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CALIGOID COPEPODS (CRUSTACEA) OF THE HAWAIIAN ISLANDS: PARASITIC ON FISHES OF THE FAMILY ACANTHURIDAE

By Alan G. Lewis[1]

Introduction

The caligoid copepods of Hawaiian fishes have not been studied previously in a systematic manner. The only references that include Hawaiian caligoids are: Nordmann (1864), describing *Norion expansus* and *Peniculus calamus*; Wilson (1924), indicating that *Pandarus satyrus* has been taken from specimens of *Prionace glauca* captured in Hawaii; and Wilson (1932), indicating that *Pandarus smithii* has been collected from sharks taken in Hawaiian waters. In addition, Edmondson (1946) figures a large *Pandarus* species from sharks and a *Lernaeenicus* species from dolphins; Bonnet (1948) lists some Hawaiian caligoids, mainly from pelagic fishes; and Randall (1958) lists by family the copepods taken from stomachs of some parasite-picking fishes of the genus *Labroides* and Randall (1961) lists the parasitic copepods taken from the manini (*Acanthurus triostegus sandvicensis*).

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The author further is grateful to Dr. Paul Illg of the University of Washington for reading the manuscript and offering suggestions for its improvement.

Finally, the author appreciates the comparison made by Dr. S. M. Shiino, of the Prefectural University of Mie, of some specimens of a copepod described in this publication with specimens in his personal collection.

METHODS.—The external surface, gill cavities, buccal cavity, and nasal cavities of the acanthurid fishes collected were examined for parasitic copepods. Copepods collected from these regions were killed and preserved in 95 percent ethyl alcohol and later transferred to 70 percent ethyl alcohol. Specimens to be dissected were placed in 85 percent lactic acid to soften and clear them, were stained with methyl blue dissolved in 85 percent lactic acid, and then were dissected in 85 percent lactic acid.

Drawings of the total animal were made with a camera lucida and a Bausch and Lomb arc projector from specimens placed in the acid and covered by a nine-millimeter cover slip. Drawings were made from appendages either in situ on the wholemount or from others dissected off and mounted in Hoyer's mounting medium. Measurements were made with an ocular micrometer.

In the following figures the ♀ and ♂ signs are used separately under each drawing to indicate a difference between the appendage of the female and that of the male, and together (♀♂) to indicate similarity of the appendages. The sex from which the drawing is made is indicated by underscoring the appropriate symbol.

TERMINOLOGY.—The term "cephalothorax" is used in the descriptions to designate the fused cephalon and two or more thoracic segments, the maxilliped-bearing segment being considered as the first thoracic segment. The term "free thoracic segments" is used to designate those segments of the thorax not fused with the head.

The term "genital segment" designates the fused fifth and sixth thoracic leg-bearing segments.

In the descriptions of all but two of the species the second antenna is described as three-segmented. This is in opposition to many of the earlier, and some of the present-day, workers. The author is accepting the viewpoint at this time that the segment attached to the ventral surface of the cephalothorax along most of its proximal surface is a distinct segment.

The spinelike projection just lateral and posterior to the base of the second antenna is called here the postantennal process; the spinelike projection just lateral to the base of the mouth cone, the postoral process. With this terminology, the two pairs of appendages between the mouth cone and the first thoracic legs become the maxillae and maxillipeds respectively. Applying the term "postantennal process" to the structure immediately behind and lateral to the second antennae is in opposition to Wilson (1905), Heegaard (1947), and others who apply the term "first maxilla" to the process. Excluding the word "cuticular" from the term "postantennal process" is in contrast with Gurney (1927), Lang (1948), and others, but indicates the present author's desire neither to accept nor to reject the belief that the process is not a true appendage. The application of the term "postoral process" to the structure immediately lateral to the base of the mouth cone is in contrast to all other workers who term the process a "maxilla." Both the postantennal and postoral processes are unsegmented, spinelike structures innervated by subesophageal nerves that arise from the same region of the ganglion (Scott, 1901; Wilson, 1905; Lewis, unpublished). Each process possesses at least one setule-bearing nodule. The fact that there is no evidence of segmentation suggests that these structures are not true appendages. Although both are innervated by subesophageal nerves, these nerves arise in close association to each other and in association with a subesophageal nerve that innervates parts of the body musculature and not the musculature associated with any of the oral appendages. The presence of at least one setule-bearing nodule may or may not offer evidence that the processes are appendages, since single setules are found on parts of the body not associated with any appendage.

The mandible here is considered "parted," not segmented. The exact derivation of the adult mandible is not known but the lack of distinct musculature and the indistinct divisions among the parts indicate that a true segmented condition does not exist in the adult appendage.

The term "chitinized," as here used, is synonymous with the term "sclerotized."

In an attempt to provide more characters for the identification of the species in the larger groups, mainly in the genera *Caligus* and *Lepeophtheirus*, the position and composition of the articular surfaces in some of the appendages (the second antenna, maxilla, and maxilliped) have been given. This characteristic appears to be constant although its later use and applicability in the separation of the species should determine its value.

The thoracic leg armature table used by Shiino in his series of publications on caligoid copepods has been adopted with slight modifications by the present author. Such a table gives the number and approximate position of the membranes, spines, and setae found on the first four pairs of thoracic legs. A hypothetical thoracic leg is shown in figure 1, which designates all of the component parts of the armament of the thoracic legs discussed in tabular form in this work.

A table of the hypothetical thoracic leg is given below. When applied to a margin, the term "inner" means that margin closest to the median longitudinal axis of the body of the copepod, the term "outer" indicates that margin furthest from the median longitudinal axis, and the term "middle" indicates that margin between the two rami, applying only to the protopodite. The term "seta" designates a slender, flexible structure that may or may not be plumose. The term "setule" is used to indicate a small seta whether single (s) or forming a fringe (C, c). The term "spine" is used to indicate a stiff, sharply pointed or blunt-tipped projecting process. (For a complete explanation of symbols, see figure 1.)

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
	outer	f	P	rh, H′	dH	H	2H, Q		d	2p′, 2P
	inner			f, p, s	c, P	c, P	C, P′,	P	c, 2P	2P
							5P, P′			
	middle			c						

Under "Remarks" the author compares the described species with species that have morphological similarities. Since this work deals with caligoids found on Hawaiian fishes, the comparison primarily involves Indo-Pacific caligoids. Copepods from areas other than this region are used in comparison only if the resemblance to the described form is striking.

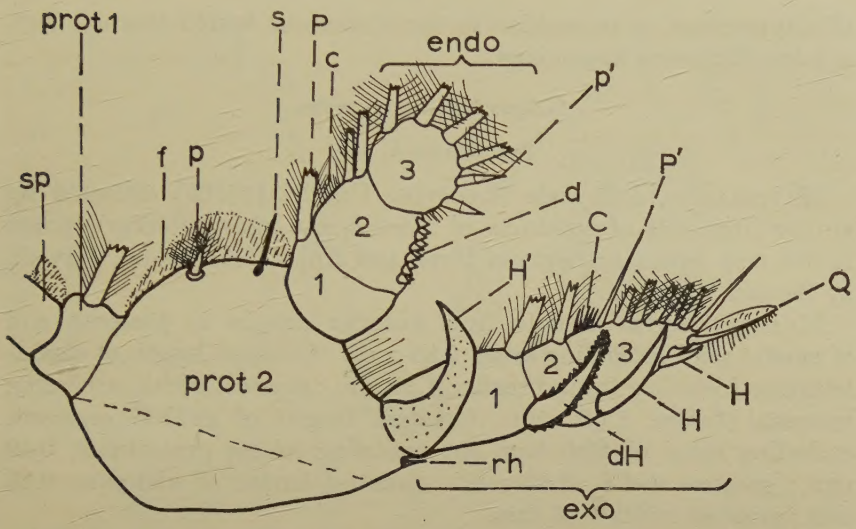

FIGURE 1.—Hypothetical thoracic leg showing various armament components:

C: heavy fringing setules
c: light fringing setules
d: denticulations
dH: denticulated spine
endo: endopodite
exo: exopodite
f: membrane
H: simple spine
H′: hooked spine
P: large plumose seta
P′: large naked seta
p: smaller plumose seta
p′: smaller naked seta
prot: protopodite
Q: seta plumose on one side with membrane on other
rh: spinule
s: solitary hairlike setule
sp: sternal plate
numbers: segment numbers

Family Caligidae

Genus *Caligus* Müller, 1785

DIAGNOSIS.—First three thoracic leg-bearing segments fused with head to form cephalothorax, fourth thoracic leg-bearing segment free, without paired dorsal plates; genital segment without plates or processes; abdomen of one or more segments. Frontal plates with lunules; sternal furca present; first three thoracic leg pairs biramous though endopodite of first pair rudimentary in the adult; fourth thoracic legs uniramous.

REMARKS.—The diagnosis presented above was modified from Wilson (1905). The second maxillae described by Wilson as simple and spinelike are, in the present work, the postoral processes which, in species such as *Caligus constrictus*, may be bifurcate. The first thoracic leg is described here, in opposition to previous workers, as biramous. The presence of an endopodite in the adult and in the developmental stages, whether rudimentary or not, indicates that

this appendage, in opposition to the uniramous fourth thoracic legs, is a true biramous appendage.

Caligus kala, new species

FIGURES 2*a–k*, 3*a–f*

MATERIAL.—Adult male (holotype, USNM 105106) collected by author from side of specimen of *Naso hexacanthus* (Bleeker), taken in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo.

MEASUREMENTS.—Length from anterior margin to posterior end of caudal rami, excluding setae, 2.85 mm. Greatest length of cephalothorax, including frontal region, 1.89 mm.; greatest width, excluding marginal flange, 1.60 mm. Greatest length of genital segment, excluding setae of fifth legs but including lobate projections, 0.49 mm.; greatest width, 0.62 mm. Greatest length of abdomen 0.29 mm.; greatest width 0.35 mm.

DESCRIPTION.—General background color of alcohol-preserved specimen dark red. Reddish spots present on dorsal surface of cephalothorax and lunules; concentration of spots from posterior edge of frontal plates to eyes, around eyes to narrow median band; median band split into two bands, one on either side of cephalothorax, continuous along margin of cephalothorax to posterior lateral extensions. Other reddish spots scattered irregularly over dorsal surface, concentrated at sutures. Eyes red. Genital segment with reddish tinge; abdomen with reddish tinge, darker along alimentary tract. Caudal rami colorless.

Cephalothorax elliptical, frontal plates large, division between frontal plates and cephalothorax distinct (fig. 2*a*). Lunules large, covering most of frontal plate area; free surface extending posteriorly on ventral surface past junction of frontal region and cephalothorax (fig. 2*c*). Division between frontal region and cephalothorax continuous, irregular in region of lunules, curving anteriorly in middle. Lateral margins of cephalothorax with narrow marginal flange. Posterior sinuses distinct, U-shaped though apex sharp, not broadly curved. Posterior sinuses with small, membranous flange attached to outer lateral surface and projecting dorsally and medially (fig. 2*a*). Posterior margin of median area of cephalothorax slightly convex, projecting slightly past posterior extension of lateral regions; lateral corners of median area sharp, margin not continuous with inner margin of posterior sinuses. Major cephalothoracic grooves distinct, in irregular H-shape. Cross and posterior longitudinal grooves continuous, broadly curved. Cross groove present in middle of cephalothorax, middle of groove extending anteriorly from junction of longitudinal grooves, apex flatly pointed. Anterior longitudinal

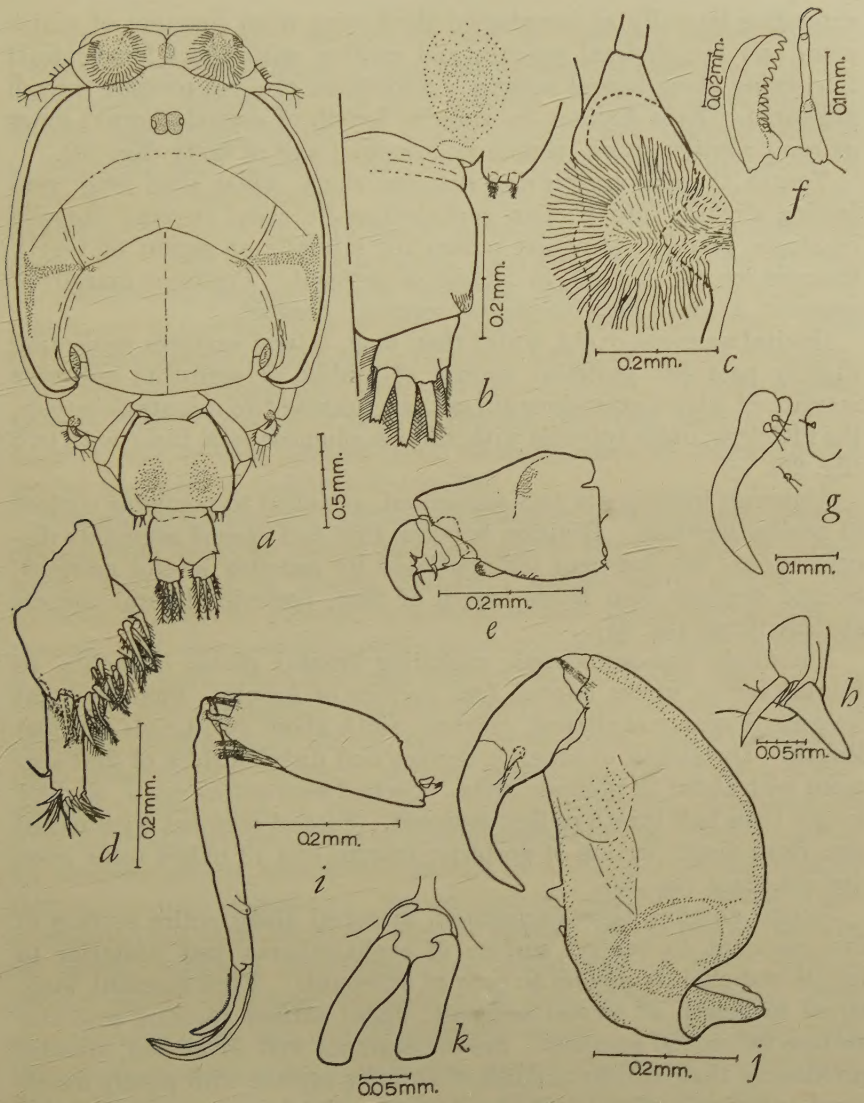

FIGURE 2.—*Caligus kala*, new species (holotype male): *a*, dorsal view; *b*, ventral view showing posterior portion of genital segment, fifth legs, abdomen, and caudal ramus; *c*, lunule; *d*, antennule; *e*, terminal two segments of second antenna; *f*, mandible and enlarged distal, toothed portion; *g*, postantennal process; *h*, postoral process; *i*, maxilla; *j*, maxilliped; *k*, sternal furca.

grooves extending from junction of longitudinal and cross grooves laterally and anteriorly, terminating at junction with indistinct, anteriorly curving cross groove. Apex of indistinct, anteriorly curving cross groove just posterior to eyes. Lateral strengthening regions

extending laterally as bar-shaped thickening from junction of major cross and longitudinal grooves and uniting with short longitudinal thickening along lateral margin. Additional grooves present though indistinct. Eyes distinct, in anterior fourth of cephalothorax; inner margins contiguous on median longitudinal axis of body (fig. 2*a*).

Fourth thoracic leg-bearing segment short, wider than long, projecting slightly into median cephalothoracic area; covered dorsally by single, platelike structure protruding laterally at region of fourth thoracic leg attachment, in middle of segment. Posterior margin of segment, at junction with genital segment, distinct.

Genital segment ovoid, wider than long, lateral surfaces projecting slightly past flat posterior margin of middle of segment; posterior margins of lateral extensions almost flat, bearing two minute tubercles, the fifth legs; outer tubercle with minute, plumose seta, inner with two (fig. 2*b*).

Abdomen indistinctly two-segmented, attached to posterior surface of genital segment. Division between first and second segments discontinuous, first segment differentiated by rounded lateral margins. Second segment four times length of first, posterior lateral corners slightly flared (fig. 2*b*).

Antennule two-segmented, excluding frontal plates, attached to frontal region under lateral, free surface of lunule. First segment irregularly diamond-shaped, greatest width about two-thirds greatest length. Distal half of anterior surface and distal surface of first segment with about 22 plumose setae. Second segment elongate, slightly longer than half length of first segment. Second segment with naked seta from distal portion of posterior margin and 13 naked setae from distal surface (fig. 2*d*).

Second antenna three-segmented, attached along entire surface of first segment to ventral surface of cephalothorax just posterior to lunule and slightly medial to base of antennule. First segment long, equal to length of second segment; distal surface forming articular surface for second segment. Second segment well developed, broader proximally than distally; middle of anterior surface with poorly developed adhesion surface; second adhesion surface present as a few serrated ridges on inner anterior surface in same area. Third adhesion surface present on distal end of small, lobate protrusion of distal portion of anterior surface of second segment. Distal surface of second segment irregular, inner portion sloping proximally, outer portion with flat margin; both inner and outer surfaces concave, inner portion receiving ball-shaped proximal end of third segment. Third segment short, proximal end heavily chitinized; with slightly curved, short, strongly developed terminal process projecting at sharp angle to segment. Two setalike accessory processes present on third segment,

one on anterior inner surface, second on posterior inner surface. Division between terminal process and segment distinct (fig. 2*e*).

Mandible four-parted; first part broader proximally than distally. Second part short, one-fourth length of first part, tapered sharply to junction with narrower third part. Third part elongate, with irregularly curved margins. Fourth part curved strongly inwards, outer margin with slight, chitinous thickening; outer margin with thin membrane, inner margin with eleven toothlike denticulations (fig. 2*f*).

Postantennal process simple, falciform, acuminate spine attached just lateral to proximal end of first segment of second antenna. Base of process strongly chitinized, ring-shaped; spine continuous with base. Base with two nodules, each with two minute setules. Two additional nodules present, medial to base of process, one from plate medial to anterior end of base, second from ventral surface of cephalothorax medial to posterior end of base (fig. 2*g*).

Postoral process simple, spinelike, extending posteriorly and slightly inward from base just lateral and posterior to proximal end of mouth cone. Distal end of process rounded. Large nodule present just anterior to base of process; length of nodule about half length of process; with three setalike projections, one almost as long as nodule, second and third short, less than half length of first (fig. 2*h*).

Maxilla two-segmented, attached slightly lateral to base of postoral process. First segment slightly shorter than second, wider proximally than distally; inner proximal surface protruding slightly as articular surface. Distal end of segment abruptly narrowed, extending as slim, bifurcate process; distal ends of process forming articular surface for second segment, one part of process on each side, second segment resting in crotch of process. Second segment elongate, slightly wider in middle than at either end. Simple, flexible, lobate process present on second segment, projecting from distal half of inner surface. Distal surface of second segment with two elongate spines, inner approximately one and one-third length of outer. Inner spine with thin membrane along both inner and outer margins; outer spine with frilled membrane along both inner and outer margins (fig. 2*i*).

Maxilliped two-segmented, attached medially and slightly posterior to maxilla. First segment strongly developed, with well-developed, recurved, proximal, articular projection; middle of inner margin with two small, heavily chitinized, tuberculate projections. Distal margin irregular, with several heavily chitinized articular surfaces. Second segment and terminal process falciform; second segment with spinelike accessory process from anterior surface. Terminal process with minute nodule projecting from proximal inner margin; division between terminal process and segment indistinct (fig. 2*j*).

Sternal furca situated between, and slightly posterior to, bases of maxillipeds. Base of furca short, irregular; tines appear to arise separately from base. Tines with flat, chisel-shaped tips and thickened lateral margins (fig. 2*k*).

First thoracic leg biramous though endopodite present only as minute, lobate process at junction of exopodite and protopodite. Protopodite one-segmented, proximal end rounded, with small projection from middle of proximal surface and large projection from outer lateral surface forming articular surfaces. Inner surface of protopodite with numerous minute projections giving rough appearance to region. Exopodite two-segmented; first segment slightly shorter than combined lengths of protopodite and second exopodite segment, with small spine at distal outer corner of segment and short, stiff setules along inner margin. Second segment of exopodite with three terminal spines, outer two of approximately equal length, innermost shorter, strongly curved. Middle spine indistinctly bifid at tip. Three plumose setae on inner lateral margin, all with stiff setules on proximal region (fig. 3*a*).

Second thoracic leg biramous. Protopodite two-segmented; first segment short, narrow proximally, broad distally. Second segment of protopodite broad, width about three-fourths length; length of second segment greater than two and a half times that of first segment. Exopodite three-segmented; first segment longer than combined lengths of second and third, with single, strongly developed spine from outer distal corner. Spine on first segment projecting across surface of second segment; fine membranes present on both inner and outer margins of spine. Second segment short, irregular, with strong spine from outer distal corner; spine projecting across surface of third segment, with fine membranes on both inner and outer margins. Lateral and distal margins of third segment continuous, segment with broadly rounded outline. Third segment with two spines on outer margin; first spine short, simple, second well developed, with membrane along inner margin. Endopodite three-segmented; first segment short, outer margin with slender setules on proximal region, stiff setules on distal region. Second segment longer than first or third, with row of toothlike projections along outer margin of right leg, knoblike projections along outer margin of left (figs. 3*c*,*d*). Third segment short, broadly rounded (figs. 3*b*–*d*).

Third thoracic leg biramous. Protopodite broadly flattened, platelike, with cluster of toothlike projections along outer surface and on inner proximal surface. Exopodite two-segmented; first segment irregular, with two-parted, hooklike process at junction of first segment and protopodite. Second part of hooklike process directed inward at sharp angle to first part. Second segment of exopodite

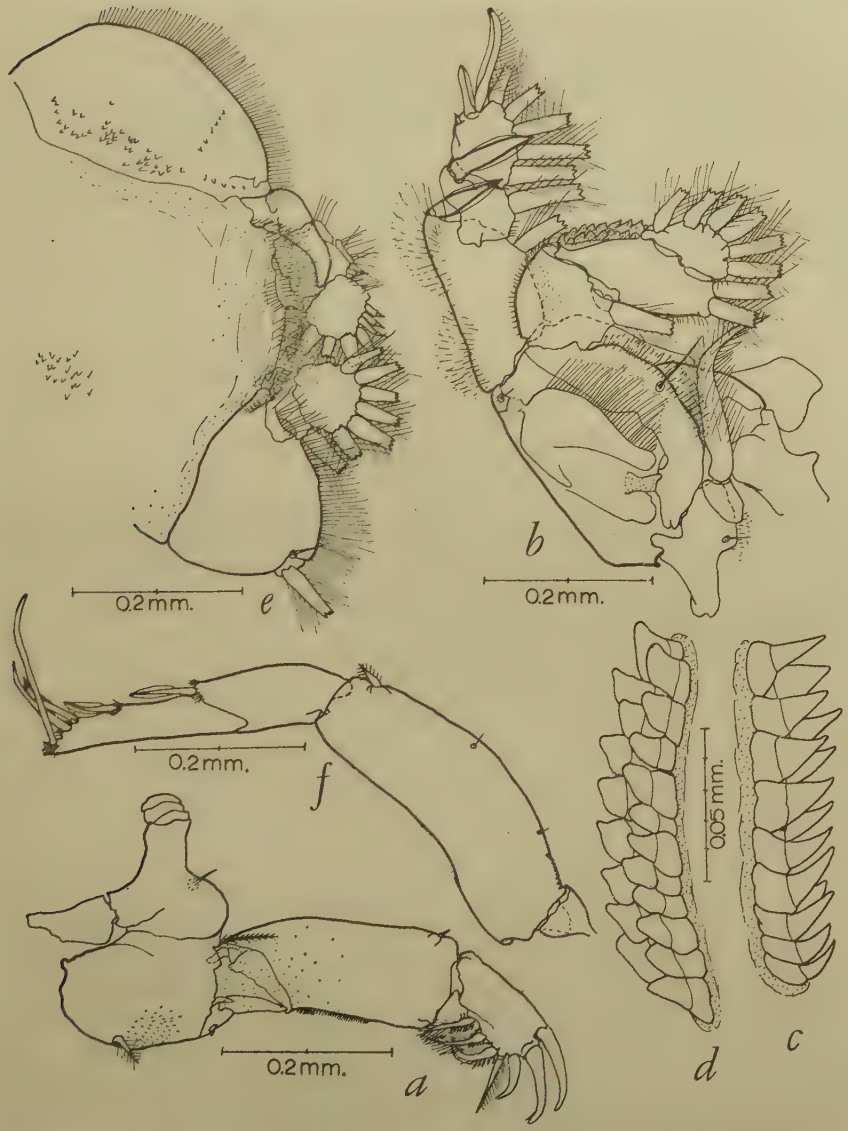

FIGURE 3.—*Caligus kala*, new species (holotype male): *a*, first thoracic leg; *b*, second thoracic leg; *c*, denticulations on outer margin of second segment of endopodite of right second thoracic leg; *d*, same as *c* except for left leg; *e*, third thoracic leg; *f*, fourth thoracic leg.

broadly rounded, lateral and distal margins continuous. Endopodite two-segmented; first segment short, proximal margin indistinct; second segment broadly rounded, lateral and distal margins continuous (fig. 3*e*).

Fourth thoracic leg uniramous, three-segmented. Protopodite one-segmented, equal to combined lengths of two segments of exopodite; middle of proximal surface projecting slightly in irregularly shaped articular surface. Protopodite with two setules projecting from outer margin and one plumose seta from outer distal surface. First segment of exopodite about two-thirds length of second, with single, membrane-margined spine at outer distal corner; base of spine ringed with frilled margin. Second segment with three spines from distal surface, one from outer lateral margin. Spine on outer margin with membrane on both outer and inner margins, base fringed with frilled margin. Inner terminal spine elongate, twice length of next longest spine, slightly curved at tip. Outer spine shortest of three, with fine membrane along outer and inner margins. All three terminal spines with bases rimmed by frilled margin (fig. 3*f*).

Caudal rami slightly wider than long, length approximately one-third length of second abdominal segment; row of setules present along inner margin. Caudal rami with five plumose setae: short seta on outer distal corner, short seta on inner distal corner, and three long setae from middle of distal margin.

The character of the armament of the thoracic legs is given below (for explanation of symbols, see figure 1):

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner		s, p p		rh c	3H 3P, P				
II	outer	f		f, s	f, H	H	h, H, Q, P	c, C	d	4P
	inner		f, P	f, s	c, P	c, P	c, 4P	P	c, 2P	c, 2P
III	outer inner middle	f	f P, s, f c		H′, c, p′ c, P	c, 3p′, P c, 3P		P	c, 3P c, 3p	
IV	outer		2s, p		H	4H				

Remarks.—Except for some minor differences in the armature of the thoracic legs, *Caligus kala*, *C. kuroshio* Shiino, 1959, and *C. bonito* Wilson, 1905, have the same thoracic leg makeup. Shiino (1959a) has indicated that *C. kuroshio* differs from *C. bonito* by a series of minor characteristics such as the position of the accessory lappet on the maxilla and the length relationships of the body parts with other parts. Basically, however, both species are similar. *C. kala* differs

from both of the above in the shape and size of the fourth thoracic leg-bearing segment, of the genital segment, and of the abdomen, which is much shorter than that of either *C. kuroshio* or *C. bonito*. In addition, the cephalic appendages of *C. kala* differ slightly from the above two species in characteristics such as the single, instead of bifid, terminal process of the second antenna.

"Kala" is the Hawaiian name for fishes of the genus *Naso*, one of which, *N. hexacanthus*, is the host from which the holotype specimen was taken.

***Caligus flexispina*, new species**

FIGURES 4*a–o*, 5*a–f*

MATERIAL.—Adult female (holotype, USNM 105103), without egg strings, taken by author from caudal fin of specimen of *Acanthurus triostegus sandvicensis* Streets speared by author in Hanauma Bay, Oahu, Hawaii. Adult male (allotype, USNM 105104), taken by author from dorsal fin of specimen of *A. t. sandvicensis* Streets speared by Robert and Donald Morris near Waikiki, Oahu, Hawaii.

MEASUREMENTS.—Holotype: Length from anterior end of body to posterior end of caudal rami, excluding setae, 2.21 mm.; greatest length of cephalothorax, including frontal region, 1.39 mm.; greatest width, excluding marginal flange, 0.90 mm. Greatest length of genital segment 0.62 mm.; greatest width 0.70 mm.

Allotype: Length from anterior end of body to posterior end of caudal rami, excluding setae, 2.30 mm. Greatest length of cephalothorax, including frontal region, 1.56 mm.; greatest width, excluding marginal flange, 1.23 mm. Greatest length of genital segment, excluding projections and setae, 0.39 mm.; greatest width 0.37 mm.

DESCRIPTION.—Female yellowish brown in alcohol, with no distinctive pigmentation marks; eyes reddish tan. Male whitish tan in alcohol, with large yellowish splotches over entire body; eyes red.

Female cephalothorax ovoid, widest posteriorly; frontal region large, lunules large (fig. 4*d*). Anterior margin of frontal region with narrow, membranous flange; division between frontal region and cephalothorax distinct, a trilobed groove, median lobe larger than lateral lobes. Lateral margins of cephalothorax with broad marginal flange. Posterior sinuses distinct, U-shaped, entrances cpen; sinuses without membranous flange. Middle of cephalothorax extending well behind posterior margins of lateral areas; posterior margin slightly convex, with small concavity in middle of margin, at junction with fourtb thoracic leg-bearing segment. Cephalothoracic grooves distinct, major grooves forming irregular H. Cross groove placed slightly anterior of middle of cephalothorax, continuous with posterior longitudinal grooves. Cross groove curving anteriorly from junction with

longitudinal grooves, slight indentation present at apex of anterior curving groove. Anterior longitudinal grooves extending laterally and anteriorly, terminating blindly slightly posterior to eyes and close to lateral margins. Lateral thickenings present as narrow bands running from just anterior to junction of cross and longitudinal grooves laterally and posteriorly, terminating in region of lateral margin. Light median groove present, extending from slight indentation at apex of cross groove to middle of posterior margin of median thoracic area. Eyes placed in anterior fourth of cephalothorax, between two short, longitudinal grooves; eye region of female two small, rounded areas, one on either side of two narrow, elongate regions slightly swollen posteriorly and contiguous on median longitudinal axis of body (fig. 4*a*).

Cephalothorax of male slightly different from that of female; widest in posterior medial region, anterior to widest point in female. Posterior margin of protruding median thoracic area convex, without median concavity of female. Cephalothoracic grooves similar to those of female though cross groove without indentation at apex. Longitudinal bars in eye region not as distinct as in female; contiguous elongations of female absent in male, eyes with inner margins touching on median longitudinal axis of body (fig. 4*b*).

Free fourth thoracic leg-bearing segment of female short, narrower at junction with third segment than at junction with genital segment. Fourth thoracic legs attached to widest point of segment, adjacent to junction with genital segment. Divisions distinct between cephalothorax and fourth thoracic leg-bearing segment and between fourth thoracic leg-bearing segment and genital segment.

Fourth thoracic legs of male joined to middle of thoracic segment, not adjacent to junction with genital segment, as in female.

Genital segment of female ovoid, widest posteriorly. Genital segment with broadly rounded lateral margins; posterior margins convex laterally, concave medially, at junction with abdomen. Fifth legs visible as three minute, plumose setae, two arising from slight projection just lateral to opening of oviduct, third from minute projection just lateral and anterior to first two (figs. 4*a*,*c*).

Genital segment of male slightly broader across posterior end than across anterior end. Posterior margin convex. Fifth and sixth legs distinct, fifth as three plumose setae from lateral region of posterior margin, two arising from single, slight protrusion, third just anteriorly, from surface of genital segment. Sixth legs of two plumose setae arising from single, lobate process extending posteriorly slightly past genital segment; inner seta almost twice length of outer (figs. 4*b*,*c*).

Abdomen of female short, length about one-fifth greatest length of genital segment; width slightly greater than greatest length (fig. 4*c*).

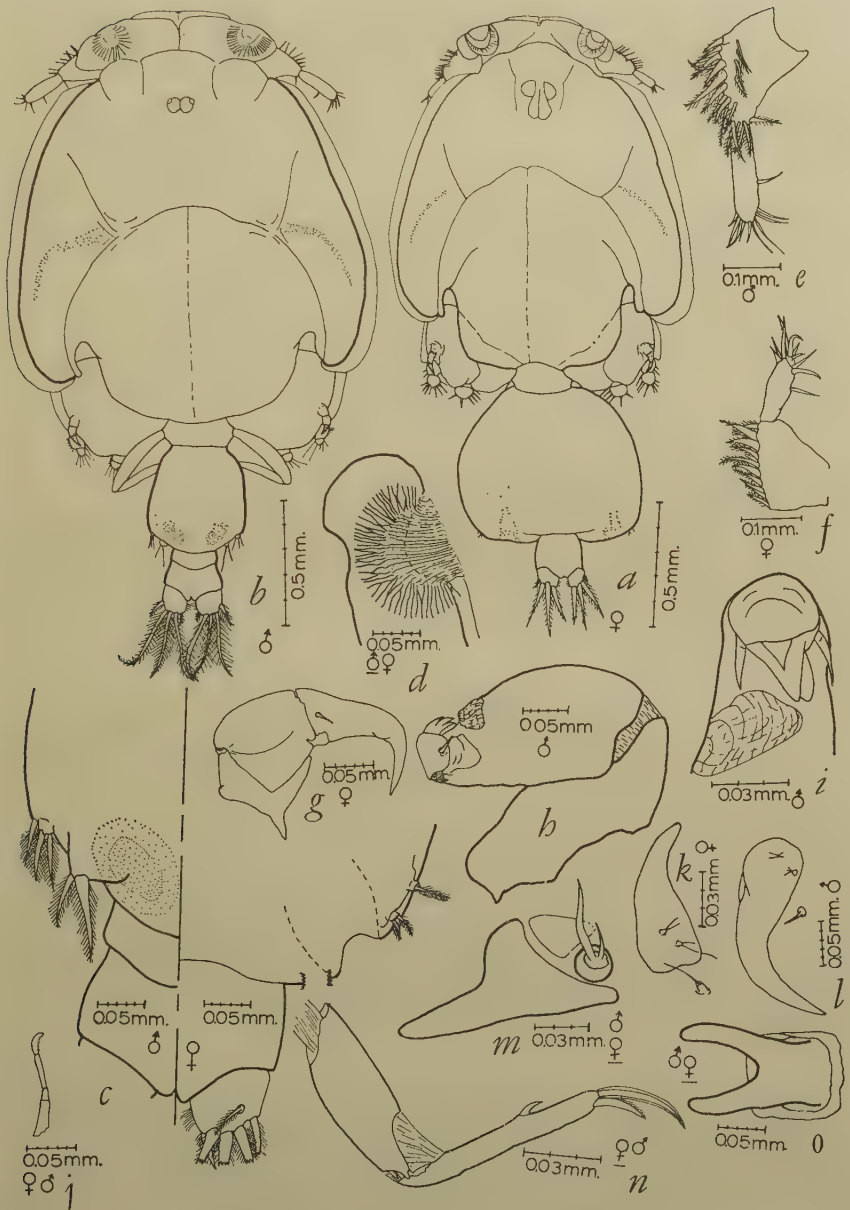

FIGURE 4.—*Caligus flexispina*, new species (holotype female, allotype male): *a*, dorsal view of female; *b*, dorsal view of male; *c*, ventral view of posterior portion of genital segment, abdomen, and caudal ramus, male on left, female on right; *d*, ventral view of lunule; *e*, antennule of male; *f*, antennule of female; *g*, second antenna of female; *h*, second antenna of male; *i*, inner surface of second segment of second antenna with adhesion pad, third segment and terminal process; *j*, mandible; *k*, postantennal process of female; *l*, postantennal process of male; *m*, postoral process; *n*, maxilla; *o*, sternal furca.

Abdomen of male arising from posterior surface of genital segment; of two distinct segments, first segment short, half length of second; second flared slightly at posterior end (fig. 4*c*).

Antennule of female two-segmented, excluding frontal plate, attached to ventral surface of cephalothorax and frontal region just medial to lateral frontal margin of frontal region. Greatest length of first segment one and a half times that of second; greatest width three-fourths greatest length. Anterior margin angular, apex of angle at widest point. First segment with twenty plumose setae on distal two-thirds of anterior margin. Greatest length of second segment more than two and a half times greatest width; proximal portion of segment narrowing abruptly at junction with first segment. Second segment with one naked seta on middle of posterior margin, twelve naked setae on distal surface (fig. 4*f*).

Antennule of male similar to that of female except second segment longer, first segment only slightly longer than second (fig. 4*e*).

Second antenna of female three-segmented, attached slightly posterior and medial to base of antennule. First segment short, forming articular surface for second segment; sharply pointed, posteriorly directed process projecting from posterior proximal surface of segment. Second segment short, strongly developed; greatest width, at proximal end, slightly less than greatest length, tapered slightly towards distal end. Inner and outer distal corners of second segment projecting slightly, heavily chitinized, serving as articular surfaces for third segment. Third segment with uncinate, acuminate terminal process; length of combined segment and process greater than length of preceding two segments. Third segment with small, spinelike accessory process on posterior proximal surface. Division between terminal process and segment not visible (fig. 4*g*).

Second antenna of male three-segmented; first segment as long as second, attached to ventral surface of cephalothorax along entire length. Proximal end of first segment with small, posteriorly directed, pointed projection; anterior end forming concave articular surface for second segment. Second segment strongly developed, with small adhesion pad on inner distal lateral surface; distal surface irregular, with several heavily chitinized regions for articulation with third segment. Third segment with trifid, spinelike terminal process. Third segment short, length including terminal process less than fourth that of second segment, with two setalike accessory processes, one from posterior medial surface of segment, second from anterior medial surface. Division between terminal process and segment distinct (figs. 4*h*,*i*).

Female and male mandible four-parted. First part long, broad proximally, with uneven taper to slightly narrower distal region.

Second part short, approximately one-third length of first part, tapering sharply to junction with third part. Third part long, slender, length of first and third parts about equal. Third part equal in width throughout entire length. Fourth part short, curved inwards; outer margin slightly thickened, inner margin thin, with 13 toothlike denticulations (fig. 4*j*).

Postantennal process of female simple, spinelike, attached lateral, and slightly posterior, to base of second antenna. Process directed posteriorly, curving medially; two minute nodules present on proximal surface, each bearing two minute setules. Larger nodule present anterior to base of process, bearing single, large setule (fig. 4*k*).

Postantennal process of male as in female, except spinelike process slender, falciform; large nodule adjacent to middle of process, not anterior to base as in female (fig. 4*l*).

Postoral process of female and male simple, located slightly lateral to base of mouth cone. Process directed posteriorly, wider at base, with sharp taper in proximal region, medial and distal portions tapered gradually to blunt, rounded tip. Postoral process with distinct node just anterior to base of process; node with two setule-like structures arising from distal surface, first setule about twice length of second (fig. 4*m*).

Maxilla of female and male two-segmented, attached just lateral and posterior to postoral process. First segment oblong, proximal surface without protruding articular surface, distal surface tapered abruptly to small, narrow, lobate projection with heavily chitinized distal end. Second segment elongate, of approximately equal width throughout; inner proximal surface with small concavity that fits over distal end of first segment as ball-and-socket joint. Second segment with strong spine on inner surface slightly distal to middle of segment. Distal end of second segment with two long spines, inner slightly less than twice length of outer, with fine, membranous margin along inner and outer surfaces; outer spine with frilled membrane along inner surface, very narrow, plain membrane along outer surface (fig. 4*n*).

Maxilliped of female two-segmented, attached slightly medial and posterior to maxilla. First segment slightly more than two times length of second segment plus processes. First segment with projection of inner proximal surface forming articular surface; lateral margins slightly convex, distal margin at angle to lateral margins, slanted sharply inward. Width of second segment less than half greatest width of first segment, tapered slightly from proximal to distal ends. Terminal process of second segment strongly developed, spinelike, curved inwards slightly, less than half length of second segment. Accessory process slender, spinelike projection from inner

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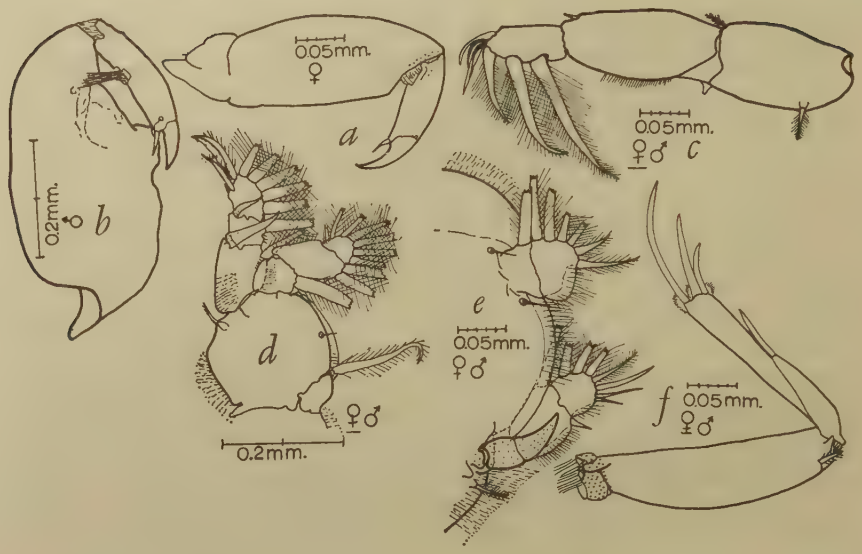

FIGURE 5.—*Caligus flexispina*, new species (holotype female, allotype male): *a*, female maxilliped; *b*, male maxilliped; *c*, first thoracic leg; *d*, second thoracic leg; *e*, third thoracic leg; *f*, fourth thoracic leg.

surface of second segment at junction of segment and terminal process. Division between segment and terminal process distinct. Terminal process and accessory process giving chelate appearance to segment (fig. 5*a*).

Maxilliped of male similar to that of female though more strongly developed. First segment with irregular inner margin; small, flat protrusion present on inner margin that receives distal end of terminal process of second segment when segment flexed (fig. 5*b*).

Sternal furca of female and male situated between, and slightly posterior to, bases of maxillipeds. Tines of furca rounded, curved slightly inwards at distal end. Greatest distance between tines equal to greatest width of base of furca. Bifurcation extending half total length of furca (fig. 4*c*).

First thoracic leg biramous though endopodite reduced to rudiment in adult. Protopodite one-segmented, with plumose seta on inner surface just proximal to middle of segment. Proximal surface without projecting articular surface but with heavily chitinized concavity on outer portion appearing to serve for articulation. First segment of exopodite slightly longer than protopodite, with small, heavily chitinized knobs protruding from distal margin as articular surfaces; with single, small spine on outer surface in distal region of segment and row of setules along inner surface. Second and terminal segment of exopodite short, half length of first segment, slender, tapered in

curved manner from broad proximal to narrow distal surface. Second segment with three flexible processes and long, naked seta on distal surface, three plumose setae on inner lateral margin (fig. 5*c*).

Second thoracic leg biramous. Protopodite two-segmented; first segment short, approximately half length of second segment. Second segment broad, with single, naked seta from outer distal corner. Exopodite three-segmented; length of first segment equal to that of second and third combined, with strongly developed spine directed inward, across surface of second segment, from outer distal corner of first segment. Second segment short, with spine similar to that of first segment though smaller; spine arising from outer distal corner and directed inward across surface of third segment. Length of third segment one and a half times that of second; general outline of segment oval. Third segment with two spines, first small, located on outer surface of middle of segment; second spine approximately four times length of first, located just distal to first spine, inner lateral margin plumose. Endopodite three-segmented; first segment short, second segment long, slightly shorter than combined lengths of first and third segments. Third segment short, half length of first segment, distal and lateral margins continuous (fig. 5*d*).

Third thoracic leg biramous. Protopodite one-segmented, flattened; length of protopodite approximately one and a half times width. Exopodite two-segmented, length of first segment almost twice that of second, with two-parted, spinelike process curving inward from junction of exopodite and protopodite. Distance between exopodite and endopodite bases slightly less than half width of protopodite. Endopodite two-segmented; first segment irregular, proximal margin indistinct. Second segment irregularly lobate, distal and lateral margins continuous (fig. 5*e*).

Fourth thoracic leg uniramous, three-segmented. Length of one-segmented protopodite slightly greater than combined lengths of two segments of exopodite. Inner proximal surface of protopodite projecting as lobate articular process. Protopodite with single, plumose seta from outer surface of distal end. First segment of exopodite less than three-fourths length of second segment, with elongate spine from outer distal surface. Second segment of exopodite with three simple spines from distal surface, each with frilled membrane around inner portion of base; frilled membrane attached to segment, not to spine. Inner spine longest, outer two spines successively shorter. Outermost spine with fine membrane along outer surface (fig. 5*f*).

The character of the membranes, spines, and setae on the thoracic legs is given below (for explanation of symbols, see figure 1):

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner		p p		rh e	3H, P′ 3P				
II	outer inner	f	f, P	f, p′ f, s	f, H e, P	H e, P	2H, h, Q e, 5P	e P	e e, 2P	e, 3P 3P
III	outer inner middle	f	f P, f, 2s e, s		H′, e, p′ P	e, 2p′, P′ e, 4P		 P	e 5P	
IV	outer		p		H	3H				

Caudal rami of female and male slightly wider than long, greatest length, excluding setae, about one-tenth length of female genital segment. Rami bearing six plumose setae; three long setae present on distal margin, short seta from each distal lateral corner, short seta from median distal ventral surface (fig. 4*e*).

Remarks.—This species is similar to *Caligus oviceps* Shiino, 1952, in the possession of flexible terminal processes on the first thoracic leg and in other thoracic leg characteristics. *C. flexispina* differs from this species in the possession of a fourth process, a naked seta, on the distal end of the first thoracic leg. In addition, *C. flexispina* possesses a distinctly separated fourth thoracic leg-bearing segment in both sexes and a distinct two-segmented abdomen in the male, while the fourth thoracic leg-bearing segment and genital segment in the female of *C. oviceps* are fused and in the male the division of the abdomen is incomplete. *C. oviceps* also possesses a four-segmented fourth thoracic leg while *C. flexispina* has a three-segmented fourth leg.

The name "flexispina" refers to the flexible terminal processes of the first thoracic leg.

Caligus randalli, new species

Figures 6*a*,*b*,*d*–*f*,*h*–*l*,*n*–*q*,7*a*–*d*

Material.—Ovigerous female (holotype, USNM 105102) collected by Dr. John Randall from epidermis of specimen of *Acanthurus triostegus sandvicensis* Streets, captured in unknown locality on Oahu, Hawaii.

Measurements.—Length from anterior end to posterior end of caudal rami, excluding setae, 4.14 mm. Greatest length of cephalo-

thorax, including frontal region, 1.84 mm.; greatest width, excluding marginal flange, 1.84 mm. Greatest length of fourth thoracic leg-bearing segment 0.29 mm.; greatest width 0.70 mm. Greatest length of genital segment 1.23 mm.; greatest width 1.03 mm. Greatest length of abdomen, excluding caudal rami, 0.90 mm. Length of egg strings 1.47 mm.; egg strings with about 28 eggs.

Because of the similarity of the holotype specimen to specimens of *Caligus constrictus* Heller, measurements were taken for comparative purposes from an ovigerous female specimen of *C. constrictus* contained in the collections of the U.S. National Museum and identified by C. B. Wilson: Length from anterior end of frontal plate to posterior end of caudal rami, excluding setae, 4.69 mm. Greatest length of cephalothorax 1.23 mm.; greatest width, excluding marginal flange, 1.93 mm. Greatest length of fourth thoracic leg-bearing segment 0.37 mm.; greatest width of fourth thoracic leg-bearing segment 0.53 mm. Greatest length of genital segment 1.84 mm.; greatest width 1.10 mm. Greatest length of abdomen, excuding caudal rami, 0.62 mm. Length of egg strings 2.34 mm. Egg strings with about 45 eggs apiece.

Description.—Holotype specimen light brown in alcohol, no evidence of pigment pattern; eyes light red.

Cephalothorax ovoid, greatest width in middle of body; frontal region narrow, division between region and cephalothorax indistinct. Lunules small, projecting slightly from anterior margin of frontal region (fig. 6*e*). Lateral margins of cephalothorax irregular, with narrow marginal flange. Posterior sinuses distinct, inner corner of lateral regions of cephalothorax overlapping outer corners of thoracic area and closing off openings to sinuses. Posterior sinuses with light, membranous flange attached to outer lateral margin and covering half of sinus. Posterior margin of thoracic area slightly convex, middle of margin projecting slightly. Cephalothoracic grooves distinct; cross groove slightly anterior to middle of cephalothorax, broadly curved, continuous with broadly curved posterior longitudinal grooves. Anterior longitudinal grooves arising from cross groove, extending anteriorly and laterally in broad curve to lateral margins. Two slender, heavily chitinized strengthening regions extending laterally from region of junction of anterior and cross grooves, terminating in region of lateral margin. Two grooves on anterior part of body extending from anterior margin of cephalothorax posteriorly slightly past eyes. Other short, indistinct grooves arising from lateral margin of cephalothorax and extending medially for short distance. Eyes distinct, placed in anterior fourth of cephalothorax, contiguous on median longitudinal axis of body (fig. 6*a*).

Fourth thoracic leg-bearing segment short, middle of segment drawn out laterally at junction of fourth thoracic legs. Posterior three-

fourths of segment covered by single, platelike structure distinctly separate from genital segment. Division between fourth thoracic leg-bearing segment and genital segment distinct (fig. 6*b*).

Genital segment longer than wide, median and posterior lateral margins parallel. Posterior lateral surfaces extending past junction of abdomen and genital segment; posterior margin forming sharp angle with lateral margin, middle of posterior margin slightly concave. Genital segment with two pairs of lobate processes projecting from posterior ventral surface (fig. 6*f*).

General outline of abdomen obovoid; length about three-fourths length of genital segment, greatest width more than half length.

Cephalothorax of *C. constrictus* circular, not ovoid as in *C. randalli*. Fourth thoracic leg-bearing segment of *C. constrictus* longer than that of *C. randalli*, anterior portion similar to *C. randalli*, posterior portion forming short, necklike extension; without platelike structure present in *C. randalli* (fig. 6*c*). Posterior lateral surfaces of genital segment forming lobate instead of angular projections (fig. 6*g*). Length of abdomen about one-third length of genital segment in contrast to relatively longer length of abdomen of *C. randalli;* greatest width four-fifths greatest length.

Antennule of *C. randalli* two-segmented, excluding frontal plate, attached to ventral surface of frontal region and cephalothorax just lateral to base of lunule; outer, free margin of lunule overlapping base of first segment of antennule. First segment of antennule broad, greatest width two-thirds greatest length. Anterior surface with approximately twenty plumose setae. Second segment elongate, greatest length 1.3 times that of first segment. Second segment with naked seta from distal portion of posterior margin, eleven naked setae from distal surface (fig. 6*h*).

Second antenna of *C. randalli* three-segmented, attached just posterior and medial to antennule. First segment forming broad, flat articular surface, with small, laterally directed, lappet-like protrusion. Second segment short, slightly longer than wide; proximal end slightly wider than distal. Second segment bearing small, lobate projection from inner distal surface. Third segment, including terminal process, elongate, length greater than two times that of second segment. Terminal process of third segment broadly curved, division between segment and process indistinct; inner terminal surface of process with minute, toothlike projections (fig. 6*i*).

Second antenna of *C. constrictus* similar to that of *C. randalli* though possessing two seta-like processes on terminal process of third segment; processes absent on *C. randalli*.

Mandible of *C. randalli* four-parted. First part slightly broader proximally than distally. Second part short, approximately two-

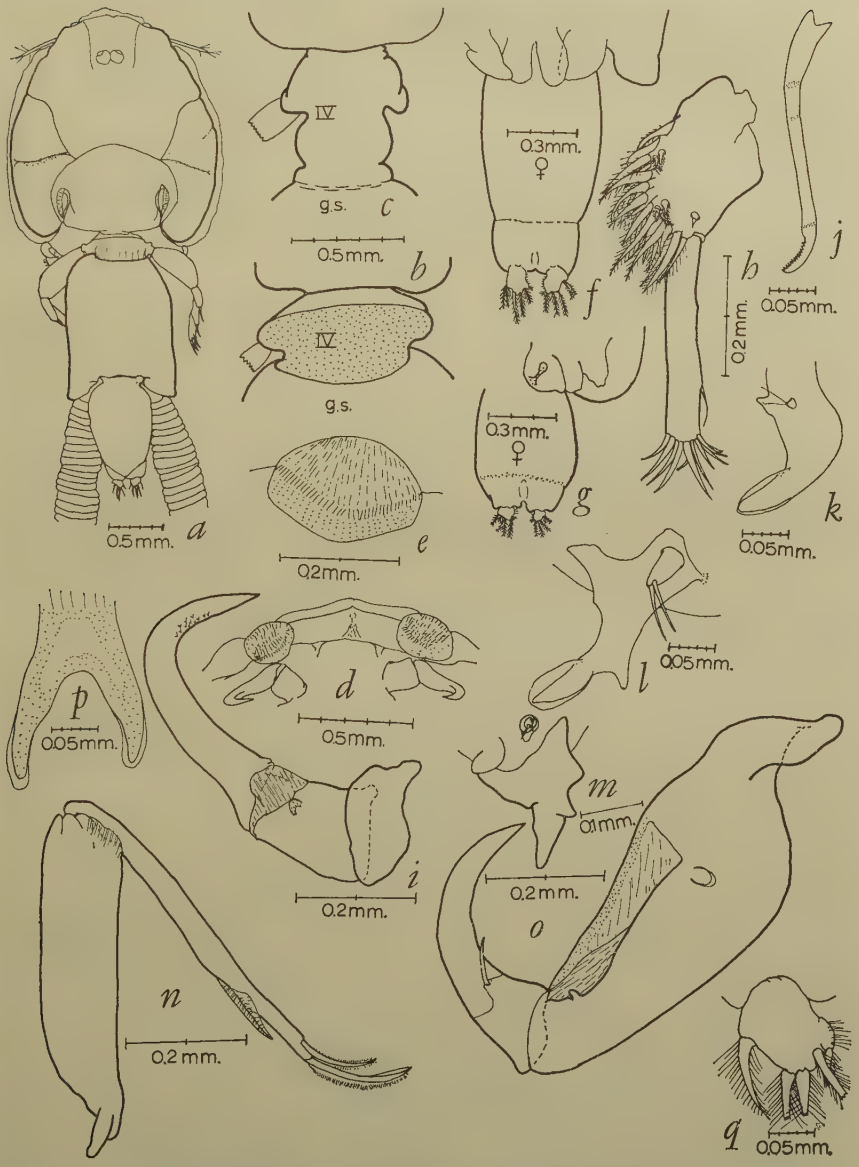

FIGURE 6.—*Caligus randalli*, new species (holotype female): *a*, dorsal view; *b*, dorsal view of fourth thoracic leg-bearing segment (g.s.=genital segment); (*c*, dorsal view of fourth thoracic leg-bearing segment of *C. constrictus*); *d*, ventral view of anterior end of cephalothorax; *e*, lunule; *f*, ventral view of posterior end of genital segment, abdomen, and caudal rami of *C. randalli*; (*g*, ventral view of posterior end of genital segment, abdomen, and caudal rami of *C. constrictus*); *h*, antennule; *i*, second antenna; *j*, mandible; *k*, postantennal process; *l*, postoral process; (*m*, postoral process of *C. constrictus*); *n*, maxilla; *o*, maxilliped; *p*, sternal furca; *q*, caudal ramus.

thirds length of first part, tapering slightly to junction with third part. Third part elongate, slightly swollen at junction of fourth part. Fourth part short, curving inwards, inner margin with 13 denticulations (fig. 6*j*).

Postantennal process of *C. randalli* a simple, curved, spinelike process situated slightly lateral and posterior to second antenna and directed ventrally and posteriorly; with small, naked, chitinous projection and single nodule bearing two long setules present on inner proximal surface (fig. 6*k*).

Postantennal process of *C. constrictus* similar to *C. randalli* though with two setule-bearing nodules and two minute spinules on inner proximal surface.

Postoral process of *C. randalli* basically single, sharply pointed process curving laterally from origin adjacent to base of mouth cone, with membrane continuous around sharply pointed distal end but with single lateral projection on inner margin giving bifurcate appearance to process. Base of process with nodule bearing two setules (fig. 6*l*).

Postoral process of *C. constrictus* with two projections from inner margin instead of one, without membrane around distal end of process.

Maxilla of *C. randalli* two-segmented, attached just lateral and posterior to postoral process. Length of first segment slightly more than four times greatest width; lateral margins parallel through most of length, projection of inner proximal surface forming articular surface. Distal margin of first segment with several lobes forming articular surfaces for second segment. Cluster of three lobes on outer part of surface forming irregular distal concavity for ball-shaped proximal end of second segment. Second segment elongate, length slightly greater than that of first segment. Middle of second segment tapered slightly, bearing folded, membranous margin and row of setules. Inner of two terminal spines 1.3 times length of outer spine, with frilled membrane on outer and inner margins. Outer spine also with frilled membrane on outer and inner margins (fig. 6*n*).

Maxilla of *C. constrictus* similar to that of *C. randalli* though lobate distal margin replaced by slight depression.

Maxilliped of *C. randalli* two-segmented, situated slightly posterior and medial to maxilla. First segment well developed, with large projection of inner proximal surface serving as articular surface. Inner surface of segment with concave depression. First segment with small, lobate projection from posterior surface just proximal to middle of segment. Distal surface of first segment irregular, with several heavily chitinized articular surfaces. Second segment short, with long, strong, falciform terminal process; length of second segment and terminal process about two-thirds length of first segment. Second

segment with small accessory spine at terminal end of segment; division between segment and process distinct (fig. 6*o*).

Maxilliped of *C. constrictus* with more distinct projection from posterior surface of first segment; with terminal process of second segment possessing minute denticulations on inner distal surface.

Sternal furca of *C. randalli* located between posterior portion of maxilliped bases. Width across base three-fifths width across tines. Bifurcation extending slightly more than half length of furca. Tines with round tips; with membrane continuous around tip of each tine (fig. 6*p*).

Tines of sternal furca of *C. constrictus* sharply pointed, not rounded as in *C. randalli*.

First thoracic leg biramous though endopodite reduced to rudiment tipped with two minute processes. Protopodite one-segmented, with inner proximal surface covered with minute projections giving segment fuzzy appearance. Two heavily chitinized knobs present as articular surfaces on proximal surface, projecting slightly from segment. First segment of exopodite long, greater than combined length of protopodite and second exopodite segment. First segment of exopodite with articular knob and small spine on outer distal corner, spine surrounded by frilled margin. Second and terminal segment of exopodite with irregular inner and distal margins; distal margin with three spines, outermost longer than inner two, triangular in cross section; inner margin of outermost spine with row of minute obtuse processes. Inner two spines on distal margin wavy, distal portion of inner margins with slight concavity, with fine membrane crossing concavity; inner margins of both spines with row of minute spinules along entire length. Inner distal corner of second segment with single, naked seta (fig. 7*a*).

Second thoracic leg biramous. Protopodite two-segmented, first segment short, approximately one-third length of second. Second segment with single naked seta on outer distal corner. Exopodite three-segmented; first segment slightly more than twice combined lengths of second and third segments, with single spine on outer distal corner, projecting across surface of second segment. Spine on first segment with serrate margins. Second segment of exopodite short, with slightly curved, serrately margined spine on outer distal corner. Third segment longer than second, ovoid, with small, serrately margined spine on outer proximal margin and slightly larger, serrately margined spine just distal to first. Endopodite three-segmented; first segment broad, outer surface lobate, rimmed with row of heavy, toothlike setules. Second segment wider than long, smaller than first segment. Third segment smaller than preceding two, distal and lateral margins continuous (fig. 7*b*).

FIGURE 7.—*Caligus randalli*, new species (holotype female): *a*, first thoracic leg; *b*, second thoracic leg; *c*, third thoracic leg; *d*, fourth thoracic leg.

Third thoracic leg biramous. Protopodite broadly flattened, with cluster of ten distinct, knoblike projections from middle of inner ventral surface and longitudinal row of toothlike projections on outer ventral surface. Exopodite two-segmented, with well-developed, two-parted, bluntly pointed process arising from junction of protopodite and first segment of exopodite and curving inwards distally. Process with membranous margin along inner distal surface. First exopodite segment slightly larger than second, wider distally than proximally; second segment rounded. Endopodite three-segmented; first segment short, second and third combined, forming flat, lobate structure; proximal end of second segment narrower than distal (fig. 7*c*).

Endopodite of third thoracic leg of all specimens of *C. constrictus* examined from collections of U.S. National Museum also three-segmented, as in *C. randalli*. This is contrary to Shiino's statement (1959b) that the endopodite is two-segmented.

Fourth thoracic leg uniramous, four-segmented. Protopodite equal to combined lengths of three segments of exopodite. Outer distal corner of protopodite with small spinule. First two segments of exopodite of approximately equal size, both rounded distally, tipped with well-developed, slightly curved spine with membranous, slightly frilled margin along outer and inner margins of spines. Spine

on first segment with indistinct frilled membrane around base, frilled membrane around base of second segment spine distinct. Third segment with three spines on distal surface, all with distinct frilled membrane around base. Innermost spine longest, outer two of approximately equal length, inner margins of all three spines lightly setuliferous (fig. 7*d*).

The character of the membranes, spines, and setae on the thoracic legs is given below. Except for minor variations such as the length and spacing of the setae, the thoracic legs of *C. constrictus* and *C. randalli* are identical. Because of this there is no comparison of these appendages in the two species. (For explanation of symbols, see figure 1.)

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner		P p		rh c	3H 3P, P′				
II	outer inner	f	P	f, p′ f, s	f, H c, P	H c, P	2H, Q, P c, 4P	c, C P	c c, 2P	c, 3P 3P
III	outer inner middle	f	f, c P, f, 2s c		H′, c, p′ c, P	c, 2p′, P′ c, 4P		P	c c, 2P	c, P 3P
IV	outer		rh		2s, H	H	3H			

Width of caudal rami about equal to length, with six plumose setae; two long setae from middle of distal surface and two each from inner and outer distal surfaces. Inner margin setuliferous. Caudal rami arising from distal ventral surface of abdomen (fig. 6*q*—one of inner setae not visible).

Remarks.—The differences between *C. randalli* and its closest relative, *C. constrictus* Heller, are given in the general description of *C. randalli*. *C. constrictus* was not taken from Hawaiian acanthurid fishes, nor has it been taken from other fishes that have been collected from this area. *C. constrictus* has been described from the west coast of Central and North America, and the author has collected specimens (to be published) on fishes of Eniwetok atoll. These two species appear closely related morphologically although there are some distinct differences between them. The major differences are the length of the abdomen and the shape and length of the fourth thoracic leg-bearing segment. The abdomen of *C. randalli* is one and a half times the length of the abdomen of *C. constrictus;* the fourth thoracic leg-bearing segment of *C. constrictus* is 1.3 times that of *C. randalli* and does not possess the platelike structure present on the dorsal surface

of the fourth thoracic leg-bearing segment of *C. randalli*. The sum of the differences between the two species—including the differences in the outline of the cephalothorax, the minor differences in the appendages, and the major differences listed above—indicate that, though the two exhibit many common characteristics and appear to be closely related, they should be considered separately.

This species is named in honor of Dr. John Randall, whose work (1961) on the biology of the manini, *Acanthurus triostegus sandvicensis*, the host of the holotype specimen of this copepod, includes a study of the parasites of the fish.

Caligus ligatus, new species

FIGURES 8*a–q*, 9*a–d*

MATERIAL.—Adult male (holotype, USNM 105107) taken by author from external surface of specimen of *Acanthurus dussumieri* Cuvier and Valenciennes captured in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Immature female (paratype, USNM 105108) taken by author from side of specimen of *Naso hexacanthus* (Bleeker) collected in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo.

MEASUREMENTS.—Holotype: Length from anterior end of body to posterior end of caudal rami, excluding setae, 2.30 mm. Greatest length of cephalothorax, including frontal region, 1.38 mm.; greatest width, excluding marginal flanges, 1.19 mm. Greatest length of genital segment, excluding setae, 0.41 mm.; greatest width 0.39 mm. Greatest length of abdomen, excluding caudal rami, 0.36 mm.

Paratype: Length from anterior end of body to posterior end of caudal rami, excluding setae, 2.05 mm. Greatest length of cephalothorax, including frontal region, 1.23 mm.; greatest width of cephalothorax, excluding marginal flanges, 1.15 mm. Greatest length of genital segment 0.39 mm.; greatest width 0.38 mm. Greatest length of abdomen 0.31 mm.

DESCRIPTION.—Male and female with brownish base color in alcohol, with scattered orange-red spots in semi-diamond shape behind eyes, scattered irregularly over rest of cephalothorax, genital segment and third thoracic legs. Eyes red.

Cephalothorax of male elliptical, frontal region distinct though width less than half that of cephalothorax. Lunules large, extending posteriorly from anterior margin to slightly past junction of frontal region and cephalothorax (fig. 8*e*). Division between frontal region and cephalothorax distinct, trilobed, median lobe larger than slightly irregular lateral lobes. Lateral margins of cephalothorax with narrow, membranous flange. Posterior sinuses distinct, narrow, U-shaped, with small, membranous flange on outer margin. Median cephalo-

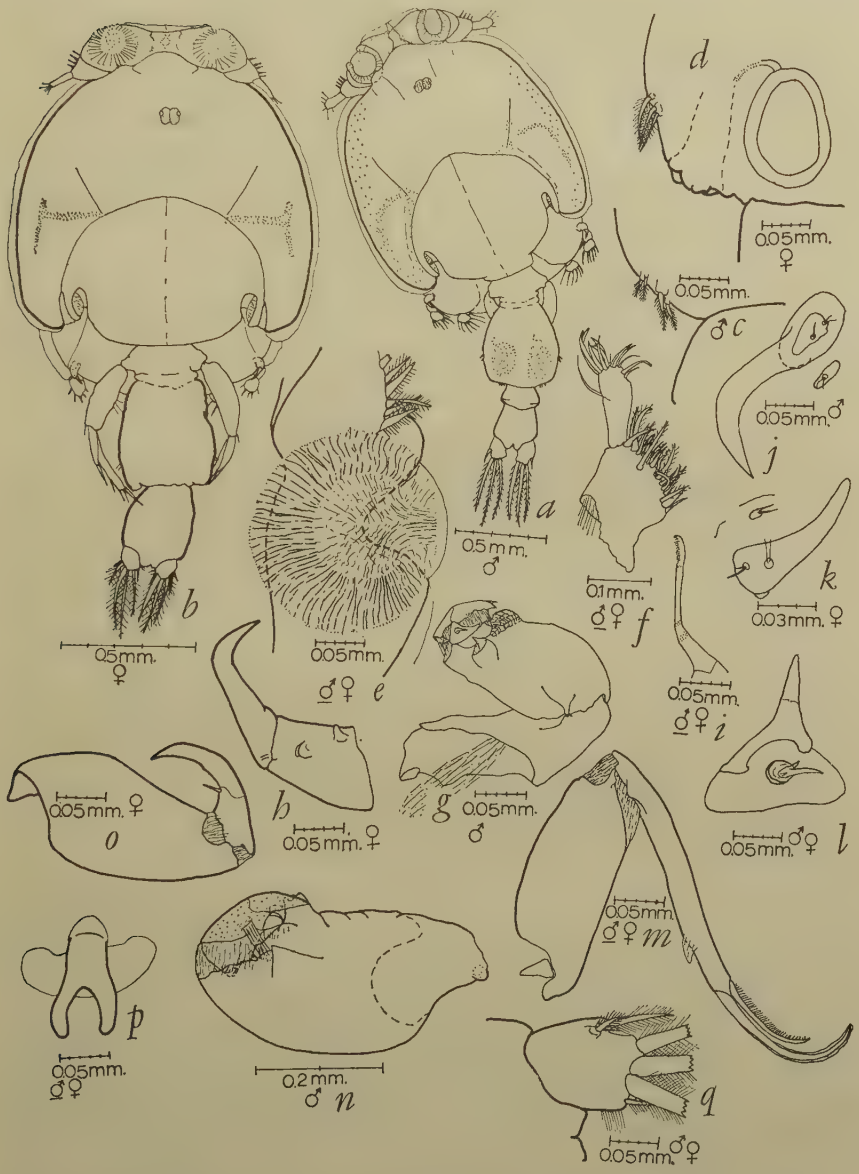

FIGURE 8.—*Caligus ligatus*, new species (holotype male, paratype immature female): *a*, dorsal view of male; *b*, dorsal view of immature female; *c*, ventral view of male fifth and sixth legs; *d*, ventral view of immature female fifth legs; *e*, ventral view of lunule; *f*, antennule; *g*, second antenna of male; *h*, terminal two segments of second antenna of immature female; *i*, mandible; *j*, postantennal process of male; *k*, postantennal process of immature female; *l*, postoral process; *m*, maxilla; *n*, maxilliped of male; *o*, maxilliped of immature female; *p*, sternal furca; *q*, caudal ramus.

thoracic area extending posteriorly past posterior ends of lateral regions; posterior margin convex, protruding slightly at junction of fourth thoracic leg-bearing segment. Cephalothoracic grooves distinct; major grooves in shape of irregular H with anterior and posterior end flared. Cross groove in middle of cephalothorax continuous with posterior longitudinal grooves, broadly curved anteriorly, apex with additional slight, anteriorly directed curve. Anterior longitudinal grooves extending anteriorly and laterally, terminating blindly posterior to eyes, in region of lateral margin. Light median groove present, extending from apex of cross groove posteriorly to posterior margin of cephalothorax. Eyes small, contiguous on median longitudinal axis of body, located in anterior fourth of cephalothorax between pair of indistinct, longitudinal grooves (fig. 8*a*).

Cephalothorax of immature female ovoid, frontal region similar to that of male, lunules slightly smaller, not extending on ventral surface past division between frontal region and cephalothorax. Posterior sinuses as in male. Median cephalothoracic area extending posteriorly slightly past lateral areas, not protruding at junction of fourth thoracic leg-bearing segment. Cross groove connecting longitudinal cephalothoracic grooves evenly curved, without slight anterior median curve present in male. Character of remaining cephalothoracic grooves as in male. Eyes slightly larger than those of male; grooves bounding eyes in male terminating anterior to eyes in immature female (fig. 8*b*).

Division between cephalothorax and fourth thoracic leg-bearing segment distinct in male and immature female. Fourth thoracic leg-bearing segment wider anteriorly, at region of fourth thoracic leg attachment, than posteriorly. Fourth thoracic leg-bearing segment fused to genital segment, posterior lateral margins lobed, constrictions between lobes appearing as fine, discontinuous lines; lobed condition more distinct in male than in immature female.

Genital segment of male small, ovoid, posterior margin slightly convex. Fifth legs appearing as two minute, plumose setae from posterior ventral lateral surface. Sixth legs present as three minute, plumose setae from slight protrusion on posterior ventral surface (fig. 8*c*).

Genital segment of immature female irregular, longer than wide; posterior margin irregular. Fifth legs visible on posterior lateral margin as group of three small, plumose setae, two projecting from single, slight protrusion of segment, third from second slight protrusion just anterior to first (fig. 8*d*).

Abdomen of male two-segmented, attached to posterior surface of genital segment. First segment short, bell-shaped, second segment

one and a half times length of first, wider posteriorly than anteriorly but tapering along posterior margins to narrow, terminal, anal region.

Abdomen of immature female one-segmented, slightly larger than second abdominal segment of male. Anterior surface slightly narrower than posterior, lateral margins broadly convex.

Antennule of male and immature female two-segmented, excluding frontal plate, attached to ventral surface of frontal region under free surface of lunule. First segment one and one-fourth times length of second; wider in middle than at either end. Proximal portion of anterior margin curving concavely outwards to widest point then convexly to narrow distal surface. Distal half of anterior margin with about 22 plumose setae. Second segment club-shaped, with naked seta on distal portion of posterior margin, 15 naked setae from rounded distal surface (fig. 8*f*).

Second antenna of male three-segmented, attached medially and slightly posterior to antennule. First segment long, length equal to that of second segment; broader proximally than distally, attached to cephalothorax along most of inner surface. Distal end of first segment irregularly concave, forming articular surface for second segment. Second segment well developed, proximal two-thirds of inner margin broadly convex, with small, slightly protruding adhesion pad just proximal to inner distal surface and small, acuminate projection on posterior distal surface. Distal surface of second segment irregular, with several articular surfaces not appearing heavily chitinized. Third segment and processes small, less than half length of second segment. Terminal process projecting slightly past region of third segment attachment, forming minute, bifid, sharply pointed structure (fig. 8*g*).

Second antenna of immature female three-segmented, much more weakly developed than that of male. First segment (not shown in figure) short, forming articular surface for second segment, with small, spinelike process projecting posteriorly from posterior margin. Second segment slightly broader proximally than distally, with small, lobate projection from proximal region of posterior surface and small, lappet-like structure from middle of distal region of posterior surface. Third segment and terminal process forming acuminate, spinelike structure; division between segment and process not visible; terminal process curving sharply inwards distally (fig. 8*h*).

Mandible of male and immature female four-parted. First part broader proximally than distally, with even taper to junction of second part. Second part short, about half length of first part, tapering sharply to junction with third part. Third part elongate, slightly swollen distally, at junction with fourth part. Fourth part short, slightly more than half length of third part, curved inward; outer

surface thicker than inner surface, inner surface with 12 toothlike denticulations (fig. 8*i*).

Postantennal process of male simple, spinelike process attached lateral to base of second antenna. Base of process a heavily chitinized ring, rest of process slender, falciform, acuminate. Two minute nodules present on basal region, each bearing minute setules. Third nodule present just posterior and medial to base, arising from small plate; third nodule with two minute setules (fig. 8*j*).

Postantennal process of immature female without ringlike base, spine heavier and shorter than that of male (fig. 8*k*).

Postoral process of male and immature female simple, spinelike structure attached lateral to base of mouth cone. Process sharply pointed, with very fine horizontal line dividing process into acuminate distal and broadly tapering proximal parts. Node present just anterior to proximal end of process and bearing three setules (fig. 8*l*).

Maxilla of male and immature female two-segmented, attached adjacent to postoral process. First segment well developed, oblong, greatest width slightly more than one-third greatest length. Lateral margins almost parallel; inner proximal surface projecting as articular surface, distal margin angling sharply inwards from both lateral margins and projecting in outer medial region as narrow articular surface with slightly concave distal end. Second segment slightly longer than first, slender, with little taper throughout length except at proximal and extreme distal ends. Small, membranous projection present on inner margin in distal third of second segment. Two elongate spines on distal end of segment, inner spine one and one-third times length of outer, with plain, light membrane along both inner and outer margins; inner spine with frilled membrane along outer margin, very fine, plain membrane along inner (fig. 8*m*).

Maxilliped of male two-segmented, located medially and slightly posterior to maxilla. First segment strongly developed, inner surface of proximal end projecting slightly as broad articular surface, with heavily chitinized knob on outer proximal corner. Distal end slightly less than half greatest width of segment. Inner lateral margin with protrusion of segment in distal region, protrusion receiving terminal process of third segment when segment flexed. Third segment and process short, less than half length of first segment, terminal process short, acuminate, slightly curved. Seta-like accessory process present on inner margin of segment at junction of segment and terminal process. Inner proximal corner with small, heavily chitinized, knoblike articular process. Division between segment and terminal process distinct (fig. 8*n*).

Maxilliped of immature female two-segmented, first segment similar to that of male except protrusion of inner surface absent. Second

segment and terminal process more elongate than in male, more weakly developed. Accessory process from inner distal margin of segment as in male; division between segment and terminal process distinct (fig. 8*o*).

Sternal furca of male and immature female situated between, and slightly posterior to, bases of maxillipeds. Bifurcation extending slightly less than half total length of structure. Tines of furca curving outwards proximally, slightly inwards distally. Distal end of tines bluntly rounded. Base of sternal furca attached to small, butterfly-shaped plate (fig. 8*p*).

First thoracic leg biramous though endopodite reduced to small protuberance on inner surface at junction of protopodite and exopodite. Single segment of protopodite slightly less than three-fourths length of first segment of exopodite, outer proximal margin with slight protrusion serving as articular surface, remaining proximal surface slightly concave, heavily chitinized. Protopodite with short, plumose seta on inner proximal surface and longer plumose seta from outer distal corner. First segment of two-segmented exopodite with spinule and protruding knob on outer distal corner. Greatest length of second segment slightly less than half that of first; distal surface with three spines and naked seta, outermost spine simple, longer than inner two, bifid-tipped spines; inner lateral margin with three plumose setae (fig. 9*a*).

Second thoracic leg biramous. Protopodite two-segmented; first segment short, second segment broad, width slightly greater than length, with small spine on outer distal corner. Exopodite three-segmented; first segment slightly longer than combined lengths of second and third, with spinule projecting from outer distal corner at base of large, well-developed spine curving inward across surface of second segment. Second segment short, about half length of third segment, with large spine projecting from outer distal corner across surface of third segment. Distal margin of third segment convex; third segment with single spine with membrane along both margins, third segment spine, with spinule present at base, on distal lateral surface. Endopodite three-segmented, first segment with single, small spine on distal outer surface; second segment equal to combined lengths of first and third segments, with row of stiff setules along outer lateral margin. Third segment short, lateral and distal margins continuous (fig. 9*b*).

Third thoracic leg biramous. Protopodite broadly flattened, with cluster of small denticulations on outer surface. Exopodite two-segmented; first segment with two-parted, spinelike process from junction of exopodite and protopodite, distal half of spinelike process curving inwards. First segment of exopodite longer than second

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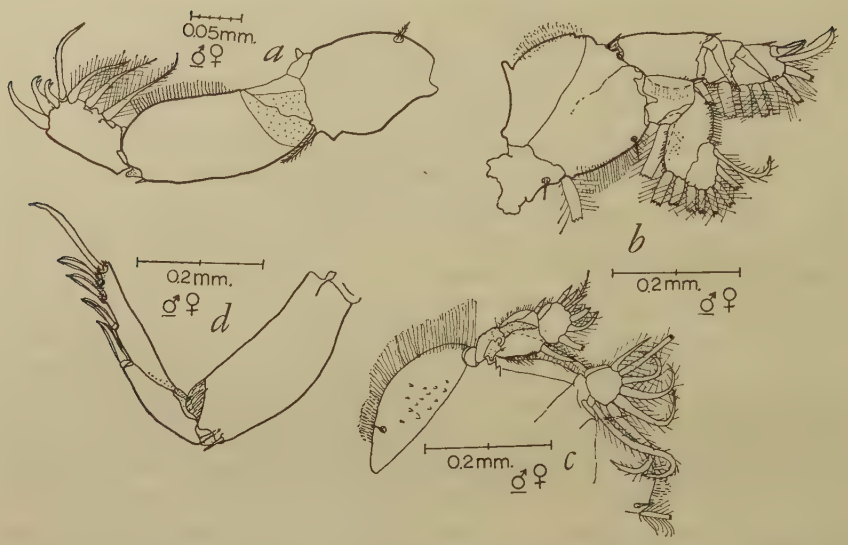

FIGURE 9.—*Caligus ligatus*, new species (holotype male, paratype immature female): *a*, first thoracic leg; *b*, second thoracic leg; *c*, third thoracic leg; *d*, fourth thoracic leg.

segment; lateral and distal margins of second segment continuous, segment with semicircular appearance. Endopodite two-segmented, proximal margin of first segment indistinct; second segment semicircular, similar to second exopodite segment in shape (fig. 9*c*).

Fourth thoracic leg uniramous, three-segmented. Protopodite one-segmented, almost equal in length to combined lengths of two segments of exopodite. Proximal surface of protopodite with small projection on inner medial portion forming articular surface; distal surface with small spine on outer portion, knoblike articular surface from median portion. First segment of exopodite short, distal end forming shelf-like projection from outer margin of segment and bearing single, well-developed spine. Second segment of exopodite with slender, rodlike process overlying inner margin of first segment. Outer and distal margins of second segment continuous, with four strongly developed spines spaced along margin, proximal spine in close proximity to terminal spine of first segment; terminal spine longest, proximal three spines of approximately equal length. Basal portion of terminal and adjacent two spines surrounded by frilled margin, that of terminal spine arising from spinelike projection of inner margin. All major spines with membrane along inner and outer margins, membranes of terminal spine minute, discontinuous (fig. 9*d*).

The character of the membranes, spines, and setae on the thoracic legs is given below. The thoracic legs of both the male and the immature female are identical except for the fourth thoracic leg which

in the immature female, is incompletely developed. (For explanation of symbols, see figure 1.)

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner		p p		rh c	3H 3P, P′				
II	outer inner		 s, P	f, rh f, s	rh, H c, P	H c, P	rh, H, Q, P c, 4P	c, rh P	C, c c, 2P	c, 4P 2P
III	outer inner middle	f	f, s P, 2s, f c		H′, c, p′ c, P	c, 3p′ c, 4P		P	c, 2P 4P	
IV	outer		rh		H	4H				

Caudal ramus of male and immature female forms about three-fourths length of second abdominal segment of male, length greater than width. Caudal ramus with six-plumose setae, one from median ventral lateral surface, second from lateral margin just posterior and lateral to base of first, three long setae from median posterior margin, and one small seta from inner posterior corner.

Remarks.—*Caligus ligatus* resembles *C. praetextus* Bere, 1936, in general body shape and the second antenna but differs from this species in the shape of the fourth thoracic leg-bearing segment and the genital segment and in the appendages other than the second antenna. The constricted shape of the region of fusion of the fourth thoracic leg-bearing segment and the genital segment is also found in *C. constrictus* Heller although the appendages of this species and those of *C. ligatus* are quite different; *C. constrictus* possesses, for example, a four-segmented fourth thoracic leg but that of *C. ligatus* is only three-segmented. The arrangement of the fourth thoracic leg spines is found in several species of *Caligus* (*C. longicervicis* Gnanamuthu, 1949; *C. sphyraenae* Nunes-Ruivo and Fourmanoir, 1956; *C. quadratus* Shiino, 1954), but the combination of characteristics presented by *C. ligatus* is unique.

The name "ligatus" is used in reference to the constrictions of the posterior portion of the fourth thoracic leg-bearing segment.

Caligus kalumai, new species

Figures 10*a–q*

Material.—Adult, nonovigerous female (holotype, USNM 105109) collected by author from side of specimen of *Acanthurus guttatus* Bloch and Schneider taken by poison near Nanakuli, Oahu, Hawaii, by Dr. William Gosline and others.

MEASUREMENTS.—Length from anterior end of body to posterior end of caudal rami, excluding setae, 2.94 mm. Greatest length of cephalothorax, including frontal region, 1.75 mm.; greatest width, excluding marginal flange, 1.75 mm. Greatest length of genital segment 0.90 mm.; greatest width 1.11 mm. Greatest length of abdomen 0.25 mm.

DESCRIPTION.—Body with light brown background coloration in alcohol, mottled with yellow and with few scattered red and blue pigment spots over cephalothorax, fourth thoracic leg-bearing segment, genital and abdominal segments. Eyes reddish.

Cephalothorax orbicular; frontal region well developed, with narrow anterior marginal flange. Lunules distinct, extending to division between frontal region and cephalothorax (fig. 10*c*). Groove between frontal region and cephalothorax distinct, continuous, curving anteriorly in smooth, flat curve in middle. Lateral margins of cephalothorax with membranous flange. Posterior sinuses distinct, U-shaped. Median cephalothoracic area extending posteriorly slightly past posterior extensions of lateral regions; posterior margin of area flattened. Lateral corners of protruding median cephalothoracic area rounded, lateral margins continuous with inner margin of posterior sinuses. Major cephalothoracic grooves distinct, forming irregular H; cross groove continuous with posterior longitudinal grooves. Middle of cross groove forming flat anteriorly directed point though apex with slight depression. Posterior longitudinal grooves slightly convex; anterior longitudinal grooves extending anteriorly and laterally from junction with cross and posterior longitudinal grooves, terminating blindly posterior to eyes, medial to lateral margin. Lateral strengthening regions extending laterally from origin just anterior to junction of longitudinal and cross grooves, curving posteriorly and tapering out in region of posterior lateral margins. Two minor grooves present, extending posteriorly from either side of anterior curvature of groove between frontal region and cephalothorax, terminating just anterior to eyes. Light median longitudinal groove present extending posteriorly from slight median depression of major cross groove to posterior margin of thoracic area. Eyes small, contiguous on median longitudinal axis of body in anterior fourth of cephalothorax (fig. 10*a*).

Fourth thoracic leg-bearing segment, genital segment, and abdomen fused. Region of fourth thoracic leg-bearing segment tapered outward sharply from junction of cephalothorax to region of fourth thoracic leg attachment, adjacent to anterior lateral surface of genital segment. Fourth thoracic leg-bearing segment tapered inward slightly from widest point to beginning of genital segment. Division between fourth thoracic leg-bearing segment and genital segment

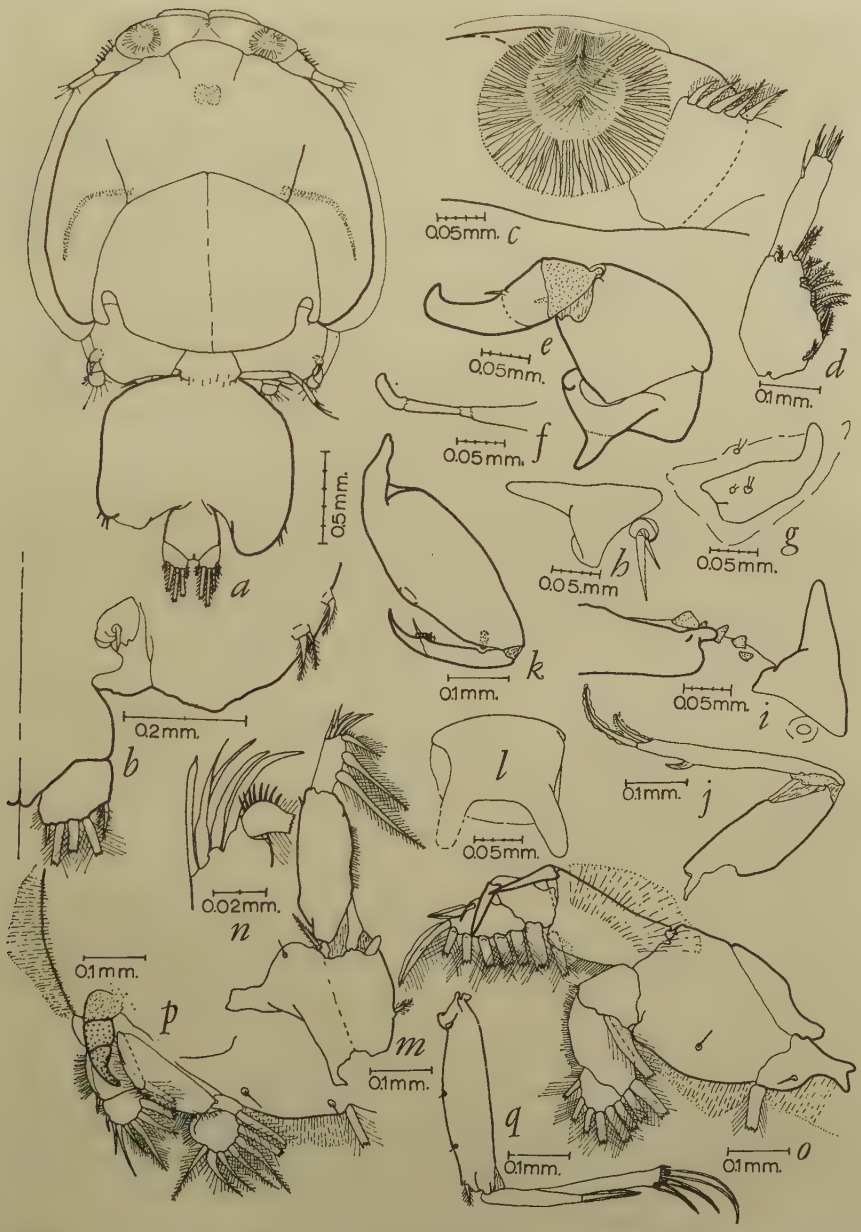

FIGURE 10.—*Caligus kalumai*, new species (holotype female): *a*, dorsal view; *b*, ventral view of fifth legs, abdomen, and caudal ramus; *c*, ventral view of lunule; *d*, antennule; *e*, second antenna; *f*, mandible; *g*, postantennal process; *h*, postoral process; *i*, projections on ventral surface of cephalothorax between postoral process and maxilla, postoral process on right, maxilla on left; *j*, maxilla; *k*, maxilliped; *l*, sternal furca; *m*, first thoracic leg; *n*, distal end of terminal segment of first thoracic leg; *o*, second thoracic leg; *p*, third thoracic leg; *q*, fourth thoracic leg.

visible as very fine groove extending from junction of segments medially, on each side, for about one-fourth width of region; no evidence of division present in middle of segment.

Genital segment swollen, lateral margins almost parallel; posterior lateral regions of segment protruding as irregular lobes; lobes extending to posterior lateral corners of abdomen. Median posterior surface depressed. Fifth legs visible dorsally as three small, plumose setae projecting from posterior lateral margin, single seta from small nodule, two setae from second nodule just posterior to first (fig. 10*b*).

Abdomen one-segmented, width approximately equal to length; widest at posterior lateral corners, margins curving medially both anteriorly and posteriorly, anteriorly in convex curve to region of fusion of abdomen and genital segment, posteriorly in concave curve to slightly projecting anal region (fig. 10*b*).

Antennule two-segmented, excluding frontal plate, attached to frontal region under free surface of lunule, at junction of frontal region and cephalothorax. Greatest length of first segment slightly more than that of second. First segment wider in proximal region than at either end, tapering abruptly to proximal end, gradually to distal; distal end irregular. Anterior surface with about 23 plumose setae. Second segment slender, slightly wider in middle than at either end. Second segment with naked seta on distal region of posterior margin, nine naked setae from distal surface (fig. 10*d*).

Second antenna three-segmented, attached posterior and slightly medial to base of antennule. First segment short, forming articular surface for second segment. Distal surface of first segment concave, posterior surface protruding posteriorly as blunt-tipped, spinelike projection. Second segment wider proximally than distally, lateral margins convex. Greatest width of second segment slightly less than greatest length. Distal margin of segment irregular, inner portion with concave depression; several points of articulation present as heavily chitinized regions. Third segment and terminal process elongate, longer than greatest length of second segment, with two accessory processes, spinelike process on posterior surface of distal end of segment and two-parted, sharp-tipped process on anterior proximal surface of segment. Base of third segment heavily chitinized, protruding slightly proximally as small, rounded articular surface. Terminal process curving sharply in distal region, distal end bluntly pointed (fig. 10*e*).

Mandible four-parted. First part wider proximally than distally, with even taper to junction of second part. Second part short, approximately one-fifth length of first part, tapered slightly to junction of third part. Third part slightly shorter than first part, expanded slightly distally. Fourth part short, half length of first part, width

greater than that of distal end of third part. Fourth part curved inward, distal end broadly rounded, inner margin with 11 blunt, toothlike denticulations (fig. 10*f*).

Postantennal process simple, blunt-tipped, spinelike process projecting posteriorly in slight curve from attachment lateral and slightly posterior to base of second antenna. Proximal surface broad, tapering sharply in middle of process to inward curving distal region. Proximal region with two nodules, each with two minute setules; additional nodule present medial to middle of process, projecting slightly from ventral surface of cephalothorax, bearing two minute setules (fig. 10*g*).

Postoral process simple, spinelike, projecting posteriorly from attachment lateral and slightly posterior to base of mouth cone. Outer lateral margin irregularly concave, inner lateral margin straight. Single nodule present anterior to base of process, bearing three setulelike projections (fig. 10*h*).

Maxilla two-segmented, attached just lateral to base of postoral process. Cephalothorax, in region of attachment of maxilla, with several small, heavily chitinized, spinelike processes (fig. 10*i*). First segment with slender projection from inner proximal surface serving as articular surface. Distal lateral margins angling sharply inward to slightly projecting articular surface. Second segment elongate, length slightly greater than greatest length of first segment; proximal surface tapered, inner portion irregular, forming articular surface. Second segment with sharply pointed spine on distal region of inner margin, two flexible spines projecting from distal surface of segment. Inner terminal spine almost twice length of outer, fringed by fine membrane along both margins; outer spine with fine, setuliferous membrane along both margins (fig. 10*j*).

Maxilliped two-segmented, situated posterior and medial to first maxillipeds. First segment obovoid, with strong projection of proximal surface forming articular surface. Middle of inner lateral margin of first segment with small, convex process. Distal surface concave, forming region of attachment and articulation of second segment; distal lateral surface with small, heavily chitinized, knoblike projection. Second segment slender, slightly wider proximally than distally; with small concavity on inner proximal margin, fitting over slight projection of distal lateral surface of first segment when second segment flexed. Second segment with short, inward-curving terminal process and two small, spinelike accessory processes, both on inner surface of distal region of segment. Both accessory processes surrounded by fine, frilled membrane. Division between terminal process and segment distinct (fig. 10*k*).

Sternal furca attached to ventral surface of cephalothorax between, and slightly posterior to, maxilliped bases. Width of base of furca equal to distance between outer distal margins of tines. Right tine broken on holotype specimen; left tine with rounded distal margin. Tines directed laterally from origin at apex of bifurcation. Bifurcation extending two-fifths length of process; apex flat, length slightly less than half width of base (fig. 10*l*).

First thoracic leg biramous though endopodite reduced to simple, minute lobe on inner distal surface of protopodite. Protopodite one-segmented, inner proximal surface extending as small articular process. First segment of two-segmented exopodite slightly longer than protopodite; proximal and distal margins irregular. First segment with single, small spine on outer distal margin. Second segment of exopodite short, less than half length of first segment. Distal margin of second segment with four flexible processes, innermost spinelike, second outermost bifid (fig. 10*n*). Inner lateral margin of second segment with three plumose setae, distalmost seta with stiff setules on proximal portion (figs. 10*m*,*n*).

Second thoracic leg biramous. Protopodite two-segmented; first segment short, proximal region slender, proximal end a two-lobed articular surface. Second segment broad, greatest width twice that of first segment; greatest length slightly more than twice that of first segment. Distal end of second segment irregular. Exopodite three-segmented; greatest length of first segment equal to that of combined second and third segments. First segment with strong, simple spine on outer distal corner, directed at angle across outer distal corner of second segment. Second segment short, with strong, simple spine on outer distal corner, directed at an angle across middle of third segment. Third segment longer than second, width greater than length; lateral margins with irregular convex curve, distal margin forming rounded apex of union of lateral margins. Outer lateral margin of third segment with two spines, small spine from middle of segment curving medially, second spine just distal to first, more strongly developed, with thin membrane along inner and outer margins. Endopodite three-segmented; first and third segments shorter than second. Third segment broadly rounded (fig. 10*o*).

Third thoracic leg biramous. Protopodite one-segmented, broadly flattened. Exopodite two-segmented, with three-parted, spinelike process arising from junction of protopodite and exopodite, and curving inward. First segment of exopodite almost twice length of second, second segment broadly rounded, distal and lateral margins continuous. Endopodite two-segmented; first segment short, with indistinct proximal margin, second segment broadly rounded laterally, flattened distally (fig. 10*p*).

Fourth thoracic leg uniramous, three-segmented. Protopodite one-segmented, slightly longer than combined length of two segments of expodite. Protopodite slender, with two hairlike setules from outer surface, one in proximal region, second in distal region; single, small, plumose seta present on outer distal corner. Greatest length of first exopodite segment slightly less than that of second; with single, elongate spine from distal surface. Second segment of exopodite with three spines on flat distal surface, inner spine longest, outer shortest. All four spines on two segments of exopodite with fine membrane along inner and outer margins; three terminal spines, on second segment, with frilled membrane around base (fig. 10*q*).

The character of the membranes, spines, and setae on the thoracic legs is given below (for explanation of symbols, see figure 1):

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner		s, p p		rh c	4H 3P				
II	outer inner	f	f, s, P	f, s	f, H c, P	H c, P	2H, Q 5P	c P	c c, 2P	c, 3P 3P
III	outer inner middle	f	f P, 2s, f c		H′, c, p′ c, P	c, 3p′ c, 3P		P	c, 2P 4P	
IV	outer		2s, P		H	3H				

Width of caudal ramus greater than length, greatest length approximately two-thirds length of abdomen; inner margin setuliferous. Six plumose setae present on distal margin, one short seta from inner corner, two short setae from outer corner, three long setae from middle of posterior margin (fig. 10*b*).

Remarks.—The fusion of the fourth thoracic leg-bearing segment, genital segment, and abdomen of *C. kalumai* is found in several members of the genus *Caligus*. In general characteristics *C. kalumai* most closely resembles *C. oviceps* Shiino, 1952, and *C. punctatus* Shiino, 1955; it differs from *C. oviceps* by the presence of three segments in the fourth thoracic leg instead of four, the nature of the terminal processes on the first thoracic leg, the presence of two naked spines on the third segment of the exopodite of the second thoracic leg instead of the single plumose spine noted by Shiino for *C. oviceps*, and by other characteristics. *C. punctatus* and *C. kalumai* differ primarily in the characteristics of the first and fourth thoracic legs, *C. punctatus* with short, stiff terminal processes on the first leg, in contrast to the longer, more flexible processes of *C. kalumai;* they

differ also in the presence of two marginal, hairlike setules on the protopodite of the fourth thoracic leg of *C. kalumai*, which are absent on *C. punctatus*. In addition, the second segment of the exopodite of *C. punctatus*, as shown by Shiino (1955), appears much longer than the first segment while it is only slightly longer than the first segment in *C. kalumai*. Other characteristics serve to differentiate these two species, but it appears that these two, in addition to *C. oviceps*, are morphologically similar.

The name "kalumai" is derived from two Hawaiian words. The first word, "kalumu," means "to swell." The second, "ma'i," is the term for genitals. The combination of the two terms is used to indicate the condition of the genital segment in the holotype female specimen.

Genus *Lepeophtheirus* Nordmann, 1832

Diagnosis.—Abdomen of one or two segments, usually distinct from genital segment. Lunules absent. Postoral process simple or bifurcate; sternal furca present. First three thoracic legs biramous though endopodite of first rudimentary; fourth leg uniramous, typically with four segments.

Remarks.—Nordmann does not give a synopsis of the characters of the genus in his 1832 publication. The characteristics given above were taken primarily from Wilson (1932) and were modified from descriptions of members of the genus *Lepeophtheirus* given by other authors and from the personal experience of the present author.

Lepeophtheirus dissimulatus Wilson

Figures 11*a–g*, 12*a–r*

L. dissimulatus Wilson, 1905a, p. 631, pl. 22.—Linton, 1907, p. 120.—Brian, 1924, p. 20.—Heegaard, 1943b, p. 20.—Yeatman, 1957, p. 350, figs. 17–31.—Shiino, 1959b, p. 305, figs. 15–16.—Causey, 1960, p. 330.

Distribution.—Bermuda, British West Indies, Dry Tortugas Islands, Galapagos Islands, Revilla Gigedo Islands, Baja California, British Columbia, Mexico, Hawaii.

Hosts.—*Epinephalus morio* (Cuvier and Valenciennes), *E. labriformis* (Jenyns), *E. guaza* (Linnaeus), *Mycteroperca venennosa apua* (Bloch), *Lactophrys trigonus?* (Linnaeus), *Gadus macrocephalus* Tilesius, *Bodianus diplotaenia* (Gill), *Merluccius productus* (Ayres), *Paralichthys californicus* (Ayres), *Hypsopsetta guttulata* (Girard), *Sphyraena argentea* Girard, *Paralabrax nebulifer* (Girard), *Sphaeroides annulatus* (Jenyns), *Galeichthys guatamelensis* (Günther), *Acanthurus olivaceous* Bloch and Schneider, *A. dussumieri* Cuvier and Valenciennes, *A. guttatus* Bloch and Schneider, *A. triostegus sandvicensis* Streets, *Naso hexacanthus* (Bleeker), *Chaetodon quadrimaculatus* Gray, *Zebrasoma flavescens* (Bennett).

MATERIAL.—Eleven adult females from gill cavity of *Acanthurus olivaceous* Bloch and Schneider (USNM 105091), ten adult females and one adult male from external surface and gill cavities of *Acanthurus triostegus sandvicensis* Streets (USNM 105092), one adult male from external surface of *Acanthurus olivaceous* Bloch and Schneider (USNM 105093), and one immature male from external surface of *Zebrasoma flavescens* (Bennett) (USNM 105090). These 24 specimens were selected from a collection of over 300 specimens taken from Oahu, Hawaii, by the author and represent the Hawaiian population of this species in the following description.

MEASUREMENTS.—Thirteen adult females: Average length from anterior margin to posterior end of caudal rami, excluding setae, 2.30 mm.; range 1.93–3.04 mm. Average of greatest length of cephalothorax, including frontal region, 1.47 mm.; range 1.01–1.93 mm. Average of greatest width of cephalothorax, excluding marginal flange, 1.47 mm.; range 1.29–1.84 mm. Average of greatest length of genital segment 0.62 mm.; range 0.49–0.78 mm. Average of greatest width of genital segment 0.70 mm.; range 0.57–0.98 mm. Average of greatest length of abdomen, excluding caudal rami, 0.12 mm.; range 0.08–0.21 mm.

One adult male: Length from anterior end of body to tips of caudal rami, excluding setae, 2.20 mm. Greatest length of cephalothorax, including frontal region, 1.58 mm.; greatest width, excluding marginal flanges, 1.42 mm. Greatest length of genital segment 0.40 mm.; greatest width 0.33 mm. Greatest length of abdomen, excluding caudal rami, 0.12 mm.

DESCRIPTION.—Body of female and male light yellow or yellowish brown in alcohol with scattered blue and few red pigment spots, some stellate, over entire body but concentrated on posterior portion of cephalothorax and genital segment. Eyes red.

Cephalothorax of female and male ovoid, frontal region distinct, separated from cephalothorax by distinct groove. Lateral margin of cephalothorax with distinct membranous flange. Posterior sinuses distinct, of shallow V-shape. Median thoracic region extending posteriorly slightly past posterior extension of lateral regions. Middle of third thoracic leg-bearing segment protruding slightly, forming junction of third and fourth leg-bearing segments. Major cephalothoracic grooves in form of irregular H with lateral distance between ends of H greater than length of anteriorly curving cross groove. Heavily chitinized, barlike strengthening process extending from region of junction of cross groove with two longitudinal grooves laterally and posteriorly, terminating in region of lateral margin. Other indistinct grooves present in region of eyes and frontal plates. Eyes distinct, situated in anterior region of cephalothorax. Two

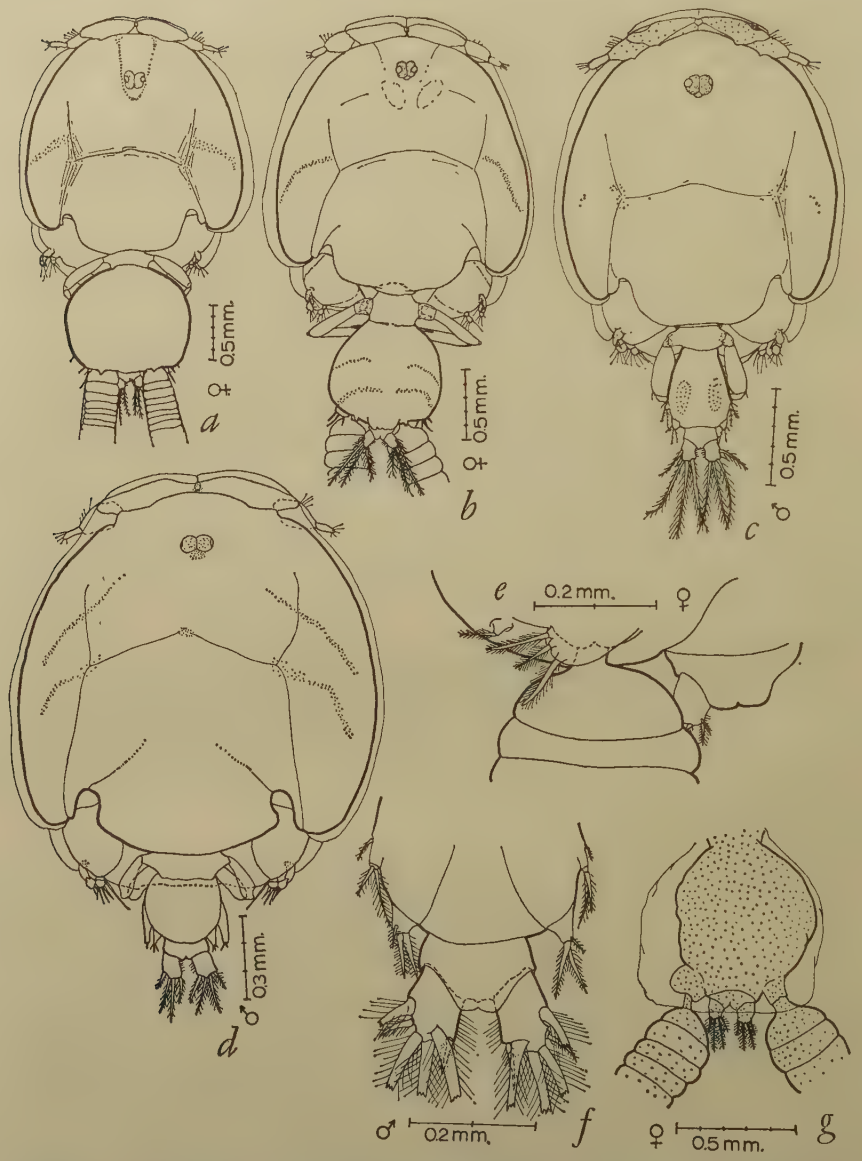

FIGURE 11.—*Lepeophtheirus dissimulatus* Wilson, 1905: *a*, dorsal view of lectotype; *b*, dorsal view of Hawaiian female; *c*, dorsal view of Hawaiian male; *d*, dorsal view of aberrant, immature Hawaiian male; *e*, ventral view of female fifth legs, proximal end of egg string, and abdomen; *f*, ventral view of male fifth and sixth legs, abdomen, and caudal rami; *g*, dorsal view of genital segment of recently ovulated female showing flaccid condition of segment.

major eyes contiguous on median longitudinal axis of body. Median eye remnant present, filling depression formed by converging posterior margins of major eyes (fig. 11*b*).

Fourth thoracic leg-bearing segment of female and male short, lateral regions drawn out in region of fourth leg attachment so that middle of segment wider than either end. Terminal portion of lateral extension cup-shaped, forming socket-like attachment for fourth thoracic legs. Division between fourth thoracic leg-bearing segment and genital segment distinct.

Shape of female genital segment variable, dependent upon number of eggs in segment. Segment flaccid and ovoid, surrounded by loose membrane, in females that recently have extruded egg strings; almost circular in females in which genital segment packed with eggs (figs. 11*b*,*g*). Fifth legs seen ventrally as lobelike projections from posterior ventral surface of genital segment, just lateral to nodelike projection of posterior surface, bearing three plumose setae; additional plumose seta present slightly lateral and anterior to first three (figs. 11*b*,*e*,*g*).

Genital segment of male ovoid, width about three-fourths length. Fifth and sixth legs distinctly visible protruding from segment. Fifth legs small, lappet-like, bearing single, short, plumose seta from base and two plumose setae from distal end, inner seta almost twice length of outer. Sixth legs also lappet-like, more distinct than fifth legs; lappet-like structure with three plumose setae from distal surface (fig. 11*f*).

Abdomen of female short, less than one-third length of genital segment. Both Wilson (1905) and Shiino (1959) indicate that the abdomen arises from the ventral surface of the genital segment. The point of attachment, however, appears to depend on the size of the genital segment. In females with an empty genital segment the abdomen joins to the ventral surface; in those with the genital segment full of eggs the abdomen attaches to the middle (in lateral view) of the posterior surface of the segment.

Abdomen of male similar to that of female though width slightly less than that of female abdomen. Junction of genital segment and abdomen on posterior ventral surface of genital segment.

Length of egg strings variable, containing 10–30 eggs with average of 15. Number of eggs in egg strings of each specimen usually equal, differing by not more than two.

Antennule of female two-segmented, excluding frontal plate, attached to frontal region near posterior lateral margin, lateral edge of frontal region overlapping first segment slightly. First segment about two times length of second, wider in proximal region than in distal, with small, bifurcate protrusion on posterior distal corner. First segment with 20 plumose setae on anterior surface. Width of second segment slightly less in proximal than in middle and distal

regions. Second segment with naked seta on middle of posterior surface, 12 naked setae on distal surface (fig. 12*a*).

Antennule of male similar to that of female except bifurcate process present on first segment more distinct, dentate instead of crenate as in female (fig. 12*b*).

Second antenna of female three-segmented, attached to ventral surface just anterior and medial to postantennal process and posterior and lateral to base of antennule. First segment short, forming broad articular surface for second segment. First segment with posteriorly directed, spinelike projection from posterior proximal surface. Second segment strongly developed, greatest width equal to greatest length. Third segment slender, heavily chitinized, with strongly developed, sharply curved, spinelike terminal process. Third segment also with two naked, seta-like accessory processes, one from inner surface of proximal region, second from distal lateral surface. Division between third segment and terminal process visible though incomplete (fig. 12*c*).

Second antenna of male three-segmented. First segment broader proximally than distally, attached to cephalothorax along entire length of proximal surface. Distal end of first segment small, two-pronged, forming articular surface for second segment. First segment with adhesion surface of heavily chitinized, overlapping, platelike structures along major portion of outer lateral surface. Second segment strongly developed; greatest width, in proximal region, slightly more than half greatest length. Outer margin strongly convex proximally, inner margin irregular due to presence of two sets of adhesion surfaces similar to those of first segment. Inner distal surface of second segment with finger-like protrusion; protrusion appearing segmented but segment-like structures probably comparable to heavily chitinized, platelike structures of other adhesion surfaces. Fingerlike protrusion not mentioned by Wilson (1905), Yeatman (1957), or Shiino (1959), but present on material identified by Wilson and Yeatman as *L. dissimulatus*. Protrusion in most specimens curved around second segment and appearing as regular adhesion surface but process not attached to second segment except at proximal end. Third segment with bifurcate terminal process, also with single, naked, seta-like accessory process from distal end (fig. 12*d*).

Mandible of female and male four-parted. First part slightly wider proximally than distally, with even taper to junction of second part. Second part shortest of four, tapered evenly from junction of first to junction of slender third part. Third part rodlike, length almost equal to combined lengths of first two parts. Fourth part slightly longer than second, flattened laterally, slightly thicker along

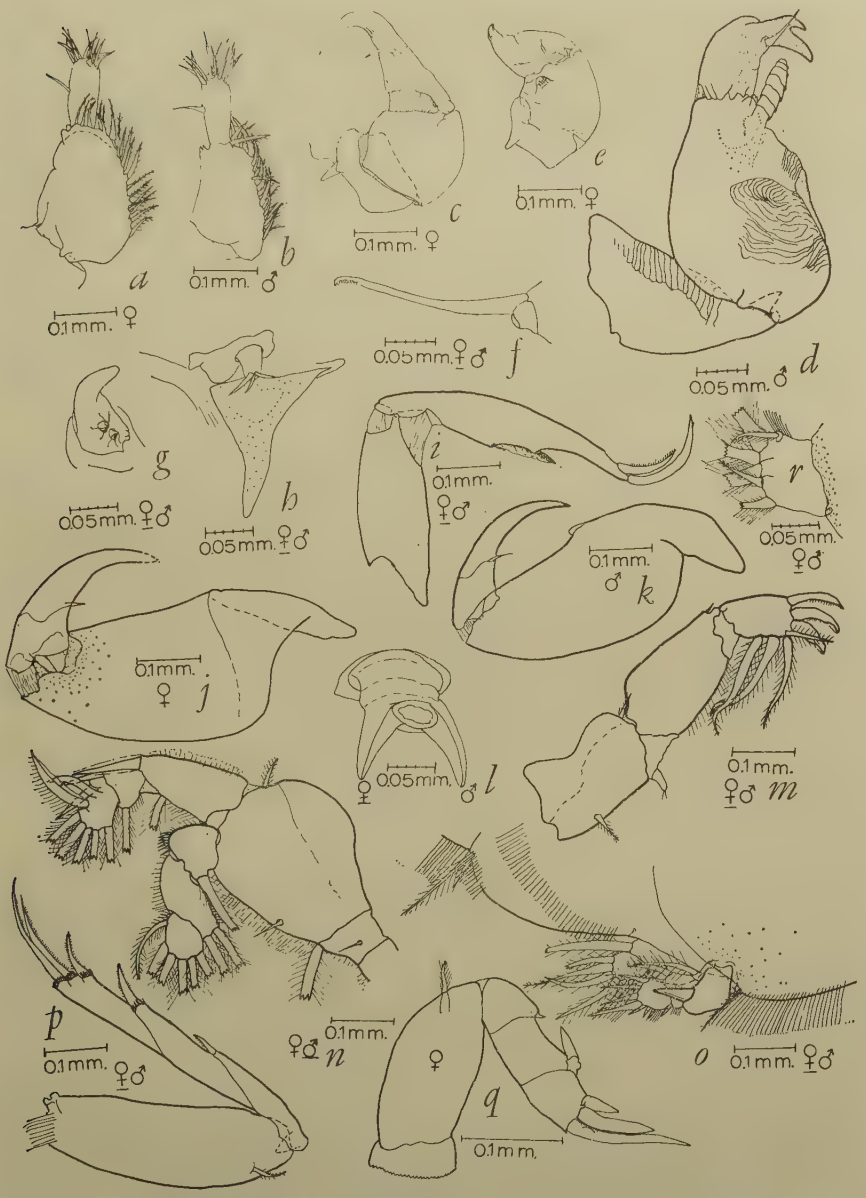

FIGURE 12.—*Lepeophtheirus dissimulatus* Wilson, 1905: *a*, antennule of female; *b*, antennule of male; *c*, second antenna of female; *d*, second antenna of male; *e*, second antenna of immature male; *f*, mandible; *g*, postantennal process; *h*, postoral process; *i*, maxilla; *j*, maxilliped of female; *k*, maxilliped of male; *l*, sternal furca; *m*, first thoracic leg; *n*, second thoracic leg; *o*, third thoracic leg; *p*, fourth thoracic leg; *q*, fourth thoracic leg of immature male; *r*, caudal ramus.

outer margin than along inner, distal half curved inwards, inner margin with 12 toothlike denticulations (fig. 12*f*).

Postantennal process of female and male simple, spinelike, attached lateral and slightly posterior to second antenna. Spinelike process curved inward, distal end rounded; two nodules present on inner proximal region, proximal nodule with three setules, distal nodule with four (fig. 12*g*).

Postoral process of female and male flattened, spinelike, situated just lateral to base of mouth cone and directed posteriorly. Process with broad base, width slightly less than length, tapered irregularly to bluntly pointed distal end. Small, conical node present just anterior to base of process, bearing three setules of approximately equal length (fig. 12*h*).

Maxilla of female and male two-segmented, attached just lateral and posterior to postoral process. First segment short, stocky, inner proximal end protruding as irregular articular surface. Distal lateral margins of first segment tapered irregularly, projecting medially as narrow, lobelike articular surface. Second segment elongate, lateral margins irregularly convex; inner proximal surface irregular, forming articular surface and place of attachment for muscles moving segment. Middle of inner margin indented in two places, minute spine arising from proximal indentation, larger spine, about twice length of first, arising from distal indentation; membrane present, connecting both spines. Smaller proximal spine and membrane not mentioned by Wilson (1905), Yeatman (1957), or Shiino (1959), though both characteristics present on material identified by Wilson and Yeatman as *L. dissimulatus*. (Both membrane and small proximal spine difficult to see unless appendage stained.) Second segment with two long, broadly curved terminal, spinelike processes; innermost about one and a half times length of outer. Inner process with membrane along inner margin and rudiments of narrow membrane along outer; outer process with frilled membrane along outer margin (fig. 12*i*).

Maxilliped of female two-segmented, attached just posterior and medial to maxilla. First segment large, strongly developed, inner proximal surface with lobate protrusion forming articular surface. Outer distal end of first segment irregular, with slightly projecting, lobate process serving as articular surface for second segment. Second segment short, with long, curved, acuminate terminal process and small, spinelike accessory process from inner distal lateral surface; division between second segment and terminal process indistinct (fig. 12*j*).

Maxilliped of male similar to that of female except with small, shelflike structure present on middle of inner margin of first segment (fig. 12*k*).

Sternal furca of female and male attached between, and slightly posterior to, bases of maxillipeds. Bifurcation extending approximately half length of process; tines with bluntly pointed tips (fig. 12*l*).

First thoracic leg biramous though endopodite present only as rudiment at junction of protopodite and exopodite. Protopodite strongly developed, one-segmented, greatest length almost equal to that of first segment of exopodite; proximal surface concave, more heavily chitinized than rest of segment, forming articular surface. Single, plumose seta present on inner proximal surface of protopodite and second, plumose seta on outer distal corner. First segment of two-segmented exopodite wider proximally than distally, proximal and distal margins irregular, proximal with slightly projecting, heavily chitinized medial surface articulating with protopodite. First segment with single spinule on outer distal corner and row of setules along inner margin. Second segment of exopodite palm-shaped, slightly more than half length of first segment, with three spines arising from distal margin and curved inwards. Inner two terminal spines with small, concave depression on distal inner margin across which fine membrane stretches; with row of stiff, very short setules along inner margin of all three spines, extending to tip of first spine, to concavity of second and third (fig. 12*m*).

Second thoracic leg biramous. Protopodite two-segmented; first segment small, less than half length of second. Second segment broad, greatest width about four-fifths greatest length, lateral and distal margins continuous, distal margin irregular. Exopodite three-segmented; length of first segment equal to combined lengths of second and third, with strongly developed, membrane-margined spine projecting distally from outer distal corner. Second segment short, irregular, with slender spine projecting distally from slight protrusion of outer distal corner. Third segment approximately twice length of second, with irregular lateral and distal margins. Two well-developed spines present on outer lateral margin of third segment, first extending distally from shelflike structure on outer proximal surface, second extending outward from attachment just distal and medial to base of first spine. Endopodite three-segmented; second segment longer than first or third. First segment with short row of stiff setules on outer distal margin; third segment rounded distally, lateral and distal margins distinct (fig. 12*n*).

Third thoracic leg biramous. Protopodite one-segmented, strongly flattened, platelike. Exopodite three-segmented; first segment with two-parted, spinelike process arising from junction of protopodite

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and second segment; second, distal, part of process directed inward at right angles to first. Second segment of exopodite flattened distally, lateral margins broadly rounded; third segment almost semicircular, lateral and distal margins continuous. Endopodite two-segmented; first segment broad; proximal margin of segment, as well as that of first exopodite segment, indistinct. Second segment of endopodite broadly rounded, distal and lateral margins distinct (fig. 12*o*).

Fourth thoracic leg uniramous, four-segmented. Protopodite one-segmented, with small, bilobed articular surface projecting slightly from inner proximal margin. Exopodite three-segmented, total length slightly more than that of protopodite. First segment of exopodite with single spine on outer distal corner; inner margin of spine with indistinct, frilled membrane. Second segment with larger spine on outer distal corner; spine with distinct, frilled membrane along inner and outer margins, base of spine encircled by minute, stiff setules. Third segment terminating in broad surface bearing three spines. Outermost spine shortest, about half length of middle spine, with frilled membrane along inner and outer margins. Middle spine slightly shorter than inner spine, with frilled membrane along outer margin only. Inner spine with few, fine setules on inner distal margin. All three terminal spines encircled by minute, stiff setules (fig. 12*p*).

The character of the membranes, spines, and setae of the thoracic legs is given below. The thoracic legs of both sexes are identical. (For explanation of symbols, see figure 1.)

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer		p		rh	3H, P				
	inner		p		e	3P				
II	outer	f	f	f, p	f, H	H	2H, Q, 2p	c, C	c	c, 3P
	inner		f, s, P	f, s	c, P	c, P	c, 3P	P	c, 2P	c, 3P
III	outer	f	f, P		H′	c, p′	3p′, P	c	c	
	inner		f, P, 2s			c, P	c, 3P	P	c, 5P	
IV	outer		p		H	H	3H			

Caudal ramus of female and male similar, width and length about equal. Inner lateral margin setuliferous; six plumose setae present on distal and distal lateral surfaces. Innermost seta small, less than one-fifth length of longest seta; three long setae from median distal margin, small seta present between these three and single seta from outer distal lateral margin (fig. 12*r*).

Aberrant immature male specimen shown in figure 11*d* (second antenna, fig. 12*e;* fourth thoracic leg, fig. 12*q*) differs from adult female and other immature males in elongate fifth and sixth leg processes. Fifth and sixth legs visible in all immature males at this stage of development but in form of small lappets, similar to those of adult male, not extremely long projections as seen in this specimen.

Remarks.—Wilson (1905) erected this species from a series of specimens from the Galapagos Islands and from Bermuda. The material that he deposited in the U.S. National Museum as the type specimens (cotypes) was that from the Galapagos. The lot (USNM 42072, numbered 1505 in Wilson's 1905 publication) contained ten females and one male taken from a specimen of *Epinephalus labriformis* (Jenyns) captured at Charles Island. At the time the present publication was prepared, the original lot contained only six females and one immature male.

Since Wilson did not select a single specimen as the holotype, the present author has taken the liberty of choosing a lectotype from the original lot. The specimen chosen was an ovigerous female 3.13 mm. in length from the anterior end of the body to the posterior end of the caudal rami, excluding the setae. Because the characters of the specimen chosen as the lectotype are in agreement with those given by Wilson (1905), only a dorsal view of the specimen is shown (fig. 11*a*).

Additional measurements of lectotype specimen: Greatest length of cephalothorax, including frontal region, 2.05 mm.; greatest width, excluding marginal flanges, 1.93 mm. Greatest length of genital segment 0.90 mm.; greatest width 1.11 mm.

Lepeophtheirus dissimulatus has been taken on both the Atlantic and Pacific coasts. It appears to be found primarily in tropical and subtropical waters although the U.S. National Museum possesses a collection, identified by C. B. Wilson and by the present author as this species, that was made in British Columbia. The size of the specimens taken in British Columbia is more than twice that of the Hawaiian specimens. The British Columbia female specimens have an average length of 6.26 mm.; the Hawaiian female specimens, an average length of 2.94 mm. The males from the British Columbia collection were only slightly larger than the single male used in the present description (3 mm. in total length to 2.20 mm. for the Hawaiian specimen).

Genus *Anuretes* Heller, 1865

Diagnosis.—Abdomen rudimentary, partially or completely fused to genital segment. Lunules absent. Fourth thoracic legs two-, three-, or four-segmented.

REMARKS.—This genus is very similar to *Lepeophtheirus*. The ten species known for the genus, including the new species described in this publication, possess only one characteristic in common: the rudimentary abdomen, and even this is not unique, *A. renalis* Heegaard having a distinct abdomen as does the male of *A. serratus* Shiino, here described for the first time. As Shiino (1954) indicates, all of the species possess characteristics in common with other members of the genus but not in common with all of the members.

Anuretes serratus Shiino

FIGURES 13*a–n*, 14*a–f*

A. serratus Shiino, 1954e, pp. 260–264, figs. 1–2.

DISTRIBUTION.—Japan, Hawaii.

HOSTS.—*Xesurus scalprum* (Cuvier and Valenciennes), *Naso hexacanthus* (Bleeker).

MATERIAL.—Male and ovigerous female (USNM 105097) collected by author from caudal fin of two specimens of *Naso hexacanthus* (Bleeker) taken in fish traps between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Two specimens selected from collection of over 100 specimens to exemplify Hawaiian population of species.

MEASUREMENTS.—Female: Length from anterior end of body to posterior end of caudal rami, excluding setae, 2.48 mm. Greatest length of cephalothorax, including frontal region, 1.85 mm.; greatest width, excluding marginal flanges, 1.56 mm. Greatest length of genital segment and fused abdomen 0.50 mm.; greatest width of genital segment 0.82 mm.

Male: Length from anterior end of body to posterior end of caudal rami, excluding setae, 1.64 mm. Greatest length of cephalothorax, including frontal region, 1.29 mm.; greatest width, excluding marginal flanges, 0.84 mm. Greatest length of genital segment and abdomen 0.45 mm.; greatest width of genital segment 0.48 mm.

DESCRIPTION.—Body of male and female opaque in alcohol, with rows of red pigment spots concentrated in posterior portion of cephalothorax and genital segment. Eyes orange-red.

Cephalothorax of female oblong, slightly longer than wide; frontal region distinct, anterior margin indistinctly crenate. Frontal region set off from cephalothorax by distinct, trilobed groove, median lobe much larger than lateral lobes. Lateral margins of cephalothorax with narrow marginal flange. Posterior sinuses distinct, deep, wider at apex than at opening, with membranous flange around most of margin. Flange not mentioned by Shiino (1954) in original description but present in both female and male specimens. Median cephalothoracic area extending posteriorly slightly past posterior extensions

of lateral regions, concealing part of fourth thoracic leg-bearing segment. Longitudinal cephalothoracic grooves distinct, cross groove absent, extending from posterior margin of cephalothorax, just lateral to openings of posterior sinuses, anterior and lateral to just behind eyes. Lateral strengthening regions visible as bar-shaped processes extending from midlateral region of cephalothorax laterally and posteriorly, terminating just medial to lateral margin of cephalothorax. Two distinct grooves extending from anterior margin of cephalothorax posteriorly and medially to region of eyes. Eyes distinct, placed in anterior fourth of cephalothorax, inner margins contiguous on median longitudinal axis of body; median eye remnant visible, contiguous with posterior margins of paired eyes (fig. 13*a*).

Fourth thoracic leg-bearing segment short but distinct, drawn out laterally, at junction of fourth thoracic legs. Division between fourth thoracic leg-bearing segment and genital segment distinct.

Genital segment of female concave at junction of fourth thoracic leg-bearing segment, broadly rounded laterally, posterior lateral surfaces forming two large lobes. Fifth legs appearing dorsally as three plumose setae, ventrally as lappet with three plumose setae, two lateral setae of equal length but shorter than single seta just medial to first two (fig. 13*c*).

Abdomen rudimentary, fused with posterior surface of genital segment, with indistinct, discontinuous line of segmentation visible in stained specimens (fig. 13*c*).

Cephalothorax of male similar to that of female except groove between frontal region and cephalothorax somewhat irregular (fig. 13*b*). Genital segment width not as great, comparatively, as in female, without posterior lateral lobes as in female. Both fifth and sixth legs visible, fifth legs as two plumose setae on posterior lateral margin of genital segment and one plumose seta slightly anterior to first two; sixth legs as small, projecting lobe with two distal, plumose setae (fig. 13*d*). Abdomen broad, short, length less than that of female, division between abdomen and genital segment distinct (fig. 13*d*).

Antennule of female two-segmented, attached to ventral surface of cephalothorax just posterior to lateral frontal region margin; not attached to frontal region. First segment about 1.7 times length of second, widest in middle of segment, anterior margin tapered on both sides of widest point. Anterior surface of first segment with 18 plumose setae. Second segment club-shaped, with one naked seta from middle of posterior margin, 13 from distal surface (fig. 13*e*).

Antennule of male similar to that of female except second segment slightly longer; with two naked setae on posterior margin instead of one as in female, one naked seta arising from middle of posterior margin, second from proximal region of margin (fig. 13*f*).

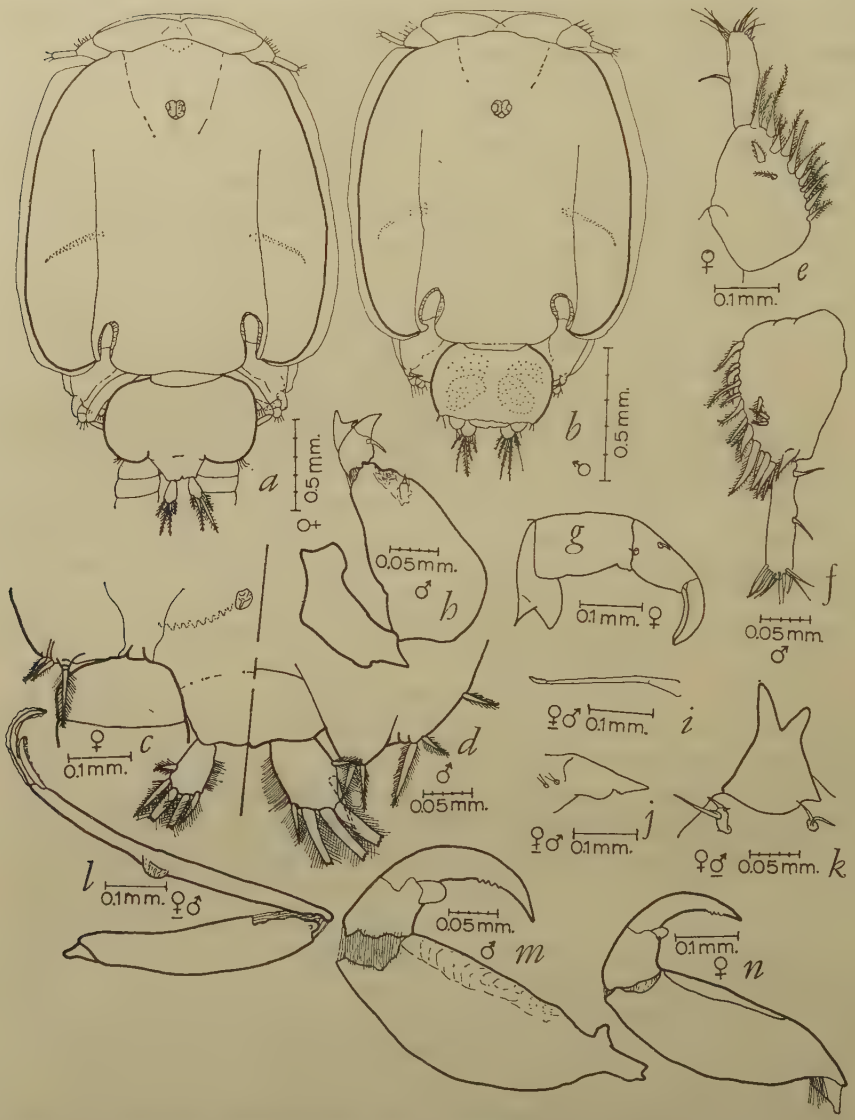

FIGURE 13.—*Anuretes serratus* Shiino, 1954: *a*, dorsal view of female; *b*, dorsal view of male; *c*, ventral view of female fifth legs, posterior end of genital segment, abdomen, and caudal ramus; *d*, ventral view of male fifth and sixth legs, posterior end of genital segment, abdomen, and caudal ramus; *e*, antennule of female; *f*, antennule of male; *g*, second antenna of female; *h*, second antenna of male; *i*, mandible; *j*, postantennal process; *k*, postoral process; *l*, maxilla; *m*, maxilliped of male; *n*, maxilliped of female.

Second antenna of female three-segmented, situated just posterior and lateral to antennule base. First segment small, forming articular surface for second segment, with triangular, posteriorly directed

process. Second segment truncate, both proximal and distal surfaces forming broad articular surfaces, distal lateral surfaces heavily chitinized. Third segment with curved terminal process and two spinules, one on proximal, second on medial inner surface. Terminal process distinct from segment, strongly developed; inner surface of process flat, lateral and outer surfaces rounded. Inner, flat surface of terminal process with minute nodules on distal portion, distal end of process tapered to sharp point (fig. 13*g*).

Second antenna of male three-segmented. First segment irregular, attached to cephalothorax along all of proximal and most of inner lateral surface; with broad articular surface on distal end. Second segment strongly developed, proximal region almost three times width of distal; inner distal surface concave, with several small adhesion pads. Third segment short, with compound terminal process and simple spinule serving as accessory process. Compound terminal process consisting of bifurcate process arising from base of simple, curved process. Accessory process arising from inner distal surface of segment (fig. 13*h*).

Mandible of female and male four-parted. First part broad at proximal end, tapered to slender distal end; second part short, tapered to junction of third part. Third part long, length greater than combined lengths of other three parts, tapered slightly to junction of fourth part; fourth part short, curved inwards, slightly thickened along outer margin, distal end rounded, 13 toothlike denticulations present along inner margin (fig. 13*i*).

Postantennal process of female and male attached lateral to base of second antenna. Process spinelike, middle with sharp bend, distal half pointing posteriorly and medially. Distal end of process bluntly pointed; inner margin swollen into distinct lobe, outer margin with small, rounded knob just proximal to sharp bend. Process with two small nodes on inner surface, each with several minute setules (fig. 13*j*).

Postoral process of female and male situated just lateral to base of mouth cone, consisting of bifurcate process and two nodules, one anterior to base of each corner of process, each bearing several setules. Two tines of bifurcation equal in female, sharply pointed; tines unequal in male, outer slightly shorter than inner, both with pointed distal ends. Acuminate condition of inner tine of process in opposition to Shiino's original description (1954) in which inner spine is indicated to be broad, distal end rounded (fig. 13*k*).

Maxilla of female and male two-segmented, attached lateral to postoral process. First segment shorter than second, narrower proximally than distally, with proximal end protruding as articular surface and small, rounded projection present on distal surface and

forming articular surface for second segment. Second segment about 1.3 times length of first, inner proximal surface with small but distinct concavity forming ball-and-socket type joint with articular surface of first segment. Second segment with sharp taper in middle, with short membrane stretched along inner surface in region of taper. Distal surface with two elongate, spinelike processes, inner almost two times length of outer, rimmed on both margins with fine membrane; outer spine rimmed on outer margin with frilled membrane (fig. 13*l*).

Maxilliped of female two-segmented, located just posterior and medial to maxilla. First segment strongly developed, ellipsoid, with short projection of proximal surface forming articular surface. Distal margin of first segment irregular, outer portion projecting above inner; distal half of inner lateral surface with distinct depression. Second segment short, with strongly curved, acuminate terminal process and small, flat, lobate accessory structure. Shiino (1954) reports the presence of a spinule on anterior side of second segment, but this spinule was not found on the female specimens examined by the present author. Division between second segment and terminal process indistinct; accessory process arising from distal end of second segment, at base of terminal process. Inner surface of terminal process flat, with minute denticulations on distal portion (fig. 13*n*).

Maxilliped of male similar to that of female except articular projection of proximal end of first segment more distinct, with additional small protrusion of inner proximal margin. Second segment and processes as in female (fig. 13*m*).

First thoracic leg biramous. Endopodite reduced to lobate, rudimentary process with distal end divided into three parts. Endopodite rudiment projecting from junction of protopodite and exopodite. Protopodite one-segmented, irregular in outline, proximal margin more heavily chitinized than rest of segment, with plumose setule present on inner distal lateral surface and plumose seta on outer distal surface. Exopodite two-segmented; first segment slightly longer than second, with spinule and round articular knob on outer distal corner. Spinule not mentioned by Shiino (1954) but present on both male and female specimens. Second segment of exopodite palm-shaped with three spines and plumose seta on distal surface. Outermost spine simple, serrate on inner margin only. Inner two spines broadly flattened, deeply serrate, serrations appearing as overlapping, spinelike extensions of terminal spine (fig. 14*a*).

Second thoracic leg biramous. Protopodite two-segmented; first segment short, second segment approximately two times length of first, width of second segment slightly less than length. Exopodite

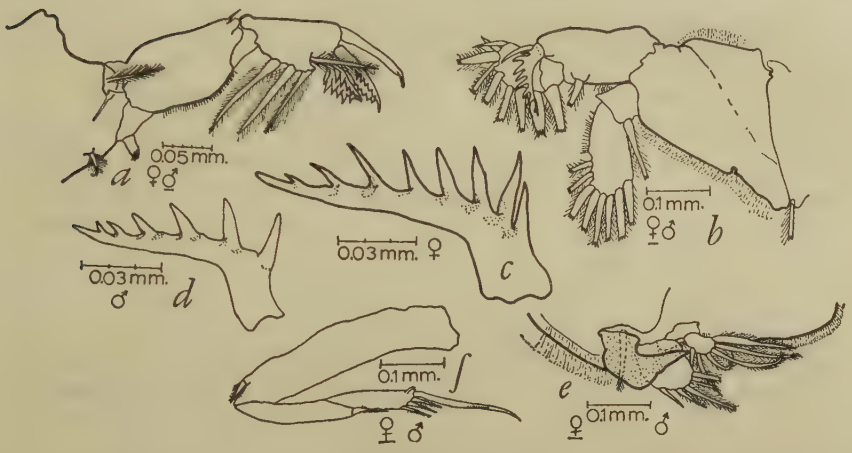

FIGURE 14.—*Anuretes serratus* Shiino, 1954: *a*, first thoracic leg; *b*, second thoracic leg; *c*, ramified spine on first segment of exopodite of female second thoracic leg; *d*, ramified spine on first segment of exopodite of male second thoracic leg; *e*, third thoracic leg; *f*, fourth thoracic leg.

three-segmented, first segment longer than combined lengths of second and third, with multiramous spine on outer distal corner. Axis of spine curving inward, rami directed distally (with regard to axis of exopodite); female with eight rami on spine, excluding tip, male with six (figs. 14*c*,*d*). Second segment of exopodite short, with single, lightly serrated spine on outer distal corner. Third segment of exopodite approximately twice length of second, with two simple spines on outer distal margin; inner and distal margins continuous. Endopodite two-segmented; second segment more than twice length of first, with eight plumose setae, all from distal half of segment (fig. 14*b*).

Third thoracic leg biramous. Protopodite broad, flat plate, semicircular in outline. Protopodite in male with adhesion pad on outer proximal surface. Exopodite one-segmented, with sharply curved, hooklike process arising from junction of exopodite and protopodite. Endopodite two-segmented, first segment short, wide; second segment about two times length of first, half the width; broadly rounded (fig. 14*e*).

Fourth thoracic leg uniramous, three-segmented. Protopodite slender, with single, plumose seta from outer distal margin. Exopodite two-segmented, shorter than protopodite; first segment with one weakly developed terminal spine, second segment with four terminal spines, outer three short, equal in length, rimmed with minute setules; inner spine almost four times length of outer three, with several minute spinules from middle of spine (fig. 14*f*).

The character of the membranes, spines, and seta on the thoracic legs is given below (for explanation of symbols, see figure 1):

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite	
			1	2	1	2	3	1	2
I	outer inner		p p		rh e	3H, p 3P			
II	outer inner	f	f P	f	f, H e, P	H P	e, 2H, Q e, 4P	e P	e, 5P e, 3P
III	outer inner	f	P, f, P P, f		H′, p′, 3P 6P			e	3P e, 3P
IV	outer		p		H	4H			

Caudal rami of female and male ovoid in general outline, width slightly more than half the length in both sexes though male slightly wider than female. Caudal rami of female shorter than abdomen, longer than abdomen in male. Five plumose setae present, three from distal surface, one from inner distal corner, one from outer distal corner (figs. 13*c*,*d*).

Remarks.—The significant characteristics of this species are the ramified spines on the third segment of the first thoracic leg and the multiramous spine on the first segment of the exopodite of the second thoracic leg.

The male of *A. serratus*, here described for the first time, differs significantly from the female only in the makeup of the second antenna, the number of branches of the multiramous spine on the first segment of the exopodite of the second thoracic leg, the characteristic male feature of the fifth and sixth legs present on the genital segment, the shorter abdomen, and the slightly larger caudal rami.

As Shiino (1954) has indicated, this species could be placed in the genus *Lepeophtheirus* were it not for the three-segmented fourth thoracic legs: members of this genus have four-segmented fourth thoracic legs. The fusion of the abdomen with the genital segment is found in some members of the genus *Lepeophtheirus;* even in *A. serratus* the abdomen of the male is distinctly separated from the genital segment. The type species of the genus *Anuretes*, *A. heckeli* (Kollar), has no distinct abdomen: it was for the members of the family Caligidae with this characteristic, in addition to the segmentation of the fourth thoracic legs, that Heller (1865) erected the genus. Since Heller's proposal of the genus, only one other species has been placed in it that has no distinct abdomen (*A. brevis* Pearse, 1951), all other species having a rudimentary or well-developed abdomen.

Because of the variety of characteristics that are exhibited by members of this genus, Shiino (1954) has aptly termed it a "waste-basket for such species that can not be located in *Lepeophtheirus*." With the description of more species in the genus, a series of characteristics may be worked out to delimit the genus more distinctly, or else the characteristics of related genera may be expanded to include the species now placed in the genus.

Anuretes menehune, new species

FIGURES 15*a–o*, 16*a–e*

MATERIAL.—Ovigerous female (holotype, USNM 105098) collected by author from dorsal fin of specimen of *Naso hexacanthus* (Bleeker) taken in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Adult male (allotype, USNM 105099) collected by author from dorsal fin of specimen of *Naso hexacanthus* (Bleeker) taken in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Three adult females and three adult males (paratypes, USNM 105101) taken by author from dorsal fin of single specimen of *Naso hexacanthus* (Bleeker) collected in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Adult ovigerous female (paratype, USNM 105100) taken by author from side of specimen of *Naso unicornis* (Forskål) speared by author at Bird Island, Oahu, Hawaii.

These specimens were taken from a collection of over 100 specimens and represent the Hawaiian population of the copepod.

MEASUREMENTS.—Holotype female: Length from anterior end to posterior end of caudal rami, excluding setae, 2.05 mm. Greatest length of cephalothorax, including frontal region, 1.44 mm.; greatest width, excluding marginal flanges, 0.86 mm. Greatest length of fused genital segment and abdomen 0.50 mm.; greatest width of genital segment 0.60 mm.

Allotype male: Length from anterior end to posterior end of caudal rami, excluding setae, 1.39 mm. Greatest length of cephalothorax, including frontal region, 1.07 mm.; greatest width, excluding marginal flanges, 0.74 mm. Greatest length of genital segment, excluding protruding fifth and sixth leg setae, 0.29 mm.; greatest width 0.29 mm.

Paratype female specimens: Average length from anterior end to posterior end of caudal rami, excluding setae, 1.68 mm. Average of greatest length of cephalothorax, including frontal region, 1.23 mm.; average of greatest width, excluding marginal flanges, 0.74 mm. Average of greatest length of genital segment and abdomen 0.43 mm.; average of greatest width of genital segment 0.49 mm.

Paratype male specimens: Average length from anterior end to posterior end of caudal rami, excluding setae, 1.31 mm. Average of

greatest length of cephalothorax, including frontal region, 0.98 mm.; average of greatest width, excluding marginal flanges, 0.57 mm. Average of greatest length of genital segment 0.28 mm.; average of greatest width 0.27 mm.

DESCRIPTION.—Body of female and male translucent in alcohol, with small, red pigment spots, some of dendritic shape, in rows on posterior portion of cephalothorax and genital segment, scattered irregularly over rest of body with heaviest concentration in lateral regions of cephalothorax.

Cephalothorax of holotype female specimen elliptical, frontal region present but reduced to undivided, platelike structure with distinct median depression of anterior margin. Anterior groove dividing cephalothorax and frontal region irregular, indistinct. Anterior margin of frontal region with narrow, membranous flange. Lateral margins of cephalothorax with narrow, membranous flange anteriorly, becoming narrower and finally disappearing posteriorly. Posterior sinuses distinct, U-shaped. Median cephalothoracic region extending posteriorly well past posterior extensions of lateral regions, covering part of fourth thoracic leg-bearing segment. Posterior margin of median extension slightly concave, lateral margins rounded, continuous with inner margins of posterior sinuses. Major cephalothoracic grooves present only as pair of longitudinal grooves, cross groove absent. Longitudinal grooves extending from posterior margin of cephalothorax, lateral to posterior sinuses, anteriorly, terminating well back of eyes; curving medially slightly posterior to middle of cephalothorax. Two lateral strengthening regions visible extending laterally and slightly posterior from middle of longitudinal grooves, in region of medial curve, to region of lateral margins of cephalothorax. Eyes small, placed well anterior, between pair of short longitudinal grooves originating at indistinct groove between cephalothorax and frontal region. Median eye remnant absent (fig. 15*a*).

Cephalothorax of allotype male similar to that of female. Frontal region present though indistinct groove separating region from cephalothorax in female absent in male. Lateral margins of cephalothorax with membranous flange continuous to beginning of posterior sinuses. Posterior margin of protruding median cephalothoracic region more concave than in female. Cross groove present though indistinct, connecting medially curved regions of longitudinal grooves (fig. 15*b*).

Fourth thoracic leg-bearing segment of holotype female specimen small, almost completely covered dorsally by median extension of thoracic region. Division between fourth thoracic leg-bearing segment and genital segment indistinct, segments at least partially fused.

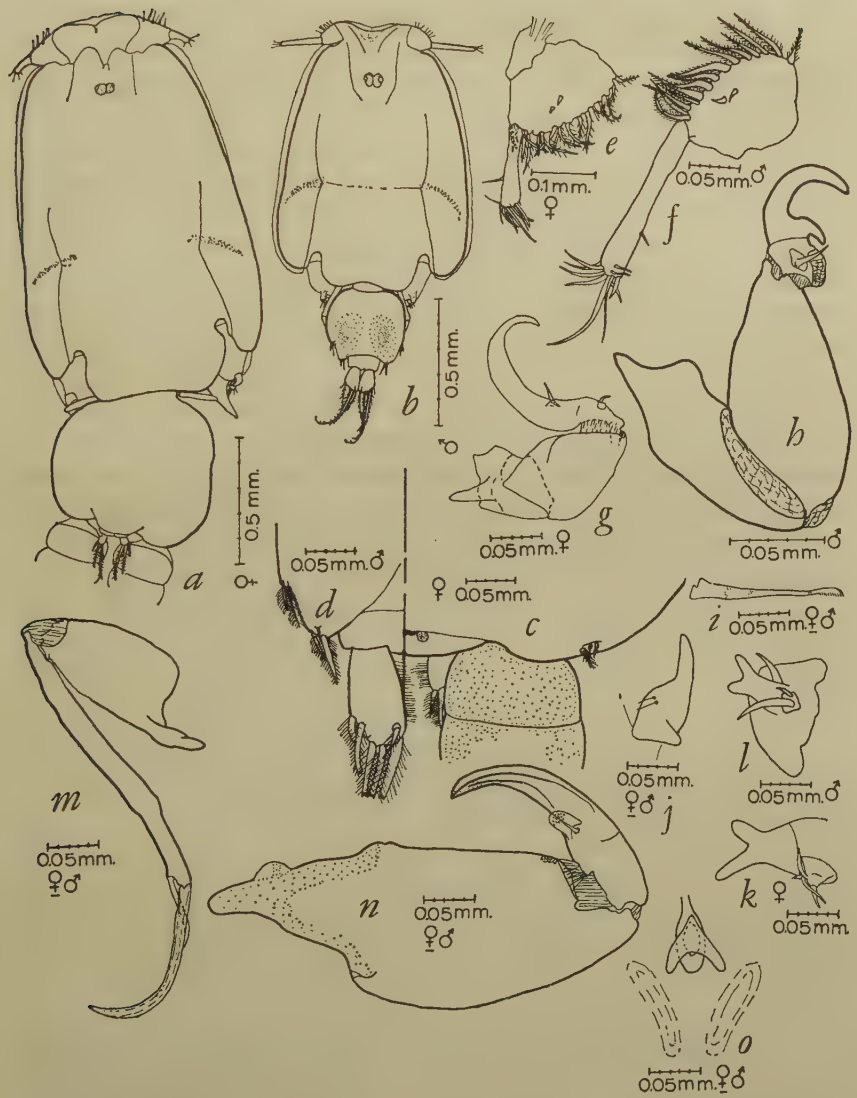

FIGURE 15.—*Anuretes menehune*, new species (holotype female, allotype male): *a*, dorsal view of female; *b*, dorsal view of male; *c*, ventral view of posterior end of female genital segment, fifth legs, abdomen, and caudal ramus; *d*, ventral view of posterior end of male genital segment, fifth and sixth legs, abdomen and caudal ramus; *e*, antennule of female; *f*, antennule of male; *g*, second antenna of female; *h*, second antenna of male; *i*, mandible; *j*, postantennal process; *k*, postoral process of female; *l*, postoral process of male; *m*, maxilla; *n*, maxilliped; *o*, sternal furca and associated processes.

Fourth thoracic leg-bearing segment of allotype male similar to female except division between segment and genital segment distinct.

Genital segment of holotype female specimen slightly wider than long, lateral margins broadly rounded, posterior lateral regions forming large lobe. Fifth legs visible as two minute spinules and single plumose setule from ventral posterior lateral surface of genital segment (fig. 15*c*).

Width of genital segment of allotype male specimen equal to length, lateral margins broadly rounded, posterior lateral regions forming smaller lobes than in female. Fifth and sixth legs distinct; fifth legs as two finely plumose setae from slight indentation of posterior lateral margin; sixth as two finely plumose setae and third, short, naked setule from distal end of lobate ventral posterior lateral surface (fig. 15*d*).

Abdomen of holotype female specimen rudimentary, fused to posterior surface of genital segment; line of division indistinct except in one paratype specimen and discontinuous in this specimen (fig. 15*c*).

Abdomen of allotype male specimen distinct, not fused to genital segment, width approximately twice length (fig. 15*d*).

Spermatophores visible on paratype female specimens as two large, circular structures attached to genital segment by necklike connection. Egg strings short, thick, approximately three-fourths length of cephalothorax, with four to six large eggs in each string.

Antennule of holotype female specimen two-segmented, excluding frontal plate, attached to cephalothorax at posterior edge of frontal region, appearing not to be attached to frontal region. First segment of general triangular shape, proximal end wider than length of segment, anterior margin curving sharply to narrow distal end, bearing 21 plumose setae; distal margin with three plumose setae, anterior dorsal surface with two naked setae. Second segment slender, club-shaped; length equal to length of first segment, with naked seta from middle of posterior margin and 10 naked setae from distal surface (fig. 15*e*).

Antennule of allotype male specimen similar to that of female though second segment much longer, approximately one and a half times that of female (fig. 15*f*).

Second antenna of holotype female specimen three-segmented, attached posterior to antennule base. First segment forming articular surface for second. First segment short, well developed, with long, triangular, distally pointed, posteriorly directed process. Second segment short, well developed, width approximately two-thirds length; with depression on distal surface forming articular surface for third segment. Third segment with recurved, acuminate terminal process; segment and process longer than combined lengths of first two segments, provided with two small, simple, spinelike processes

on proximal inner surface. Division between segment and terminal process indistinct (fig. 15*g*).

Second antenna of allotype male three-segmented. First segment long, outer surface of distal two-thirds forming articular surface for second segment, proximal margin forming blunt, posteriorly directed process. Second segment well developed, with broad base, tapered to narrow distal margin. Distal margin of second segment irregular, with heavily chitinized regions forming articular surfaces for third segment. Third segment short, with adhesion surface on inner margin, and seta-like accessory process on posterior surface adjacent to adhesion pad. Terminal process of third segment bifurcate; inner part of bifurcation curving inward and proximally as projection of basal region of process, outer part of bifurcation much longer than inner, extending distally before recurving in same manner as first part. Division between segment and terminal process distinct (fig. 15*h*).

Mandible of female and male four-parted. First part broader proximally than distally, lateral margins irregular. Length of second part approximately equal to that of first, with even taper to junction of elongate third part. Third part as long as combined lengths of first two parts, tapered slightly to junction of fourth part. Fourth part curving medially at distal end, with 11 toothlike denticulations along inner margin (fig. 15*i*).

Postantennal process of female and male simple, slightly curved spine arising lateral and posterior to attachment of second antenna. Spine with two minute nodules on inner proximal surface, each with long setule (fig. 15*j*).

Postoral process of holotype female specimen a plate with projecting bifurcate process and node, at anterior end of plate. Node with three setules of approximately equal length. Inner tine of bifurcate process longer than outer, both tines with rounded distal ends (fig. 15*k*).

Postoral process of allotype male specimen similar to holotype though setule-bearing node with two setules, third setule from base of bifurcate process (fig. 15*l*).

Maxilla of female and male two-segmented, situated lateral and slightly posterior to postoral process. First segment short, well developed, inner proximal surface protruding as lobate articular process. First segment tapered from broad base to narrow distal end, middle of distal end projecting as articular surface for second segment. Second segment elongate, one and a half times length of first segment. Inner proximal margin with small concavity forming ball-and-socket joint with articular surface of first segment. Second segment tapered abruptly in middle, as in *A. serratus*, but without membrane found in this species, with two long, spinelike processes on distal surface, inner

process more than twice length of outer, with fine membrane along inner and outer margins. Outer terminal process without membranes (fig. 15*m*).

Maxilliped of female and male two-segmented, attached medial and slightly posterior to maxilla. First segment well developed, with proximal extension of inner surface forming articular surface. First segment tapered from wide proximal to somewhat narrower distal region. Distal surface irregular, with heavily chitinized indentations for articulation with second segment. Second segment short, with strongly developed, curved, clawlike terminal process. Second segment with flat, lobate process and simple, spinelike process as accessory structures. Lobate accessory structure with minute, toothlike denticulations on distal surface. Spinelike accessory structure attached just proximal to middle of base of lobate accessory structure. Inner surface of curved terminal process flat, with very slight denticulations. Division between segment and terminal process indistinct (fig. 15*n*).

Sternal furca of female and male located between, and slightly posterior to, bases of maxillipeds. Base of furca heavily chitinized oval structure; center of base depressed, not heavily chitinized. Bifurcate process single, arrowhead-shaped unit, distinct from oval base, attached to base at proximal end. Furcal tines widely spread, with even concave depression between blunt tips; lateral margins curving medially to attachment with base. Two medially curving ridges present posterior to sternal furca (fig. 15*o*).

The arrowhead-shaped furcal process is absent in one of the paratype specimens (USNM 105100); the only structure present is the heavily chitinized oval base. In addition, both postoral processes either have been lost or have developed irregularly, since only a simple, blunt, spinelike process is present. This variation may lead to taxonomic difficulties in later work as there is no evidence of the loss of these two processes in the specimen.

First thoracic leg biramous though endopodite reduced to rudimentary, lobate process at junction of exopodite and protopodite. Protopodite one-segmented, with slight projection of outer proximal portion forming articular surface; single, lightly plumose setule present on inner proximal lateral margin. First segment of two-segmented exopodite slightly longer than protopodite, proximal and distal margins irregular, outer distal corner with projecting heavily chitinized knob and simple spinule. Second segment of exopodite palm-shaped, proximal and inner margins continuous, irregular, distal margin with three spines and plumose seta. Outermost spine lightly denticulate distally, inner two spines shorter, with small concave depression on

inner distal surface. Both inner spines flattened, lateral margins ramified into small secondary spines (fig. 16*a*).

Second thoracic leg biramous. Protopodite two-segmented; first segment small, less than half length and width of second segment. Second segment with large, club-shaped articular process protruding from outer proximal corner. Exopodite three-segmented; first segment longer than combined lengths of second and third segments, with strong spine from outer distal corner directed across surfaces of second and third segments. Second segment short, with smaller spine from outer distal corner; third segment slightly longer than second, broadly rounded, with two small spines on outer lateral margin. Endopodite three-segmented; first and second segments about equal in length, third short, broadly rounded (fig. 16*b*).

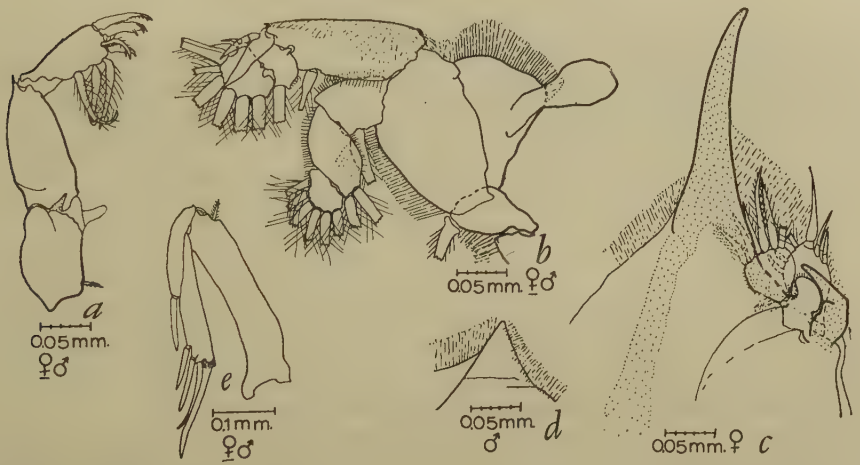

FIGURE 16.—*Anuretes menehune*, new species (holotype female, allotype male): *a*, first thoracic leg; *b*, second thoracic leg; *c*, third thoracic leg of female; *d*, protopodite process of third thoracic leg of male; *e*, fourth thoracic leg.

Third thoracic leg biramous. Protopodite one-segmented, flattened, inner surface extending posteriorly, under genital segment, as large, heavily chitinized, slightly curved, blunt-tipped process in female; male protopodite process extending slightly from segment, not as heavily chitinized as female process (figs. 16*c*,*d*). Exopodite one-segmented, with curved, one-parted process arising from junction of exopodite and protopodite. Single segment of exopodite longer than wide, broadly rounded. Endopodite two-segmented; first segment broad, with broad distal lobe; second segment broadly rounded, attached to inner corner of first segment (fig. 16*c*).

Fourth thoracic leg uniramous, three-segmented. Protopodite one-segmented, longer than combined lengths of two exopodite

segments; with single, plumose setule on outer distal margin. Distal end of first segment of exopodite tipped with strong spine reaching to distal region of second segment. Second segment with four spines, inner three borne on distal surface, outer on distal lateral margin. Innermost spine longest, base surrounded by ring of stiff setules fused at base into solid structure. Outer three terminal spines successively shorter, outermost shortest (fig. 16*e*).

The character of the membranes, spines, and setae present on the thoracic legs is given below (for explanation of symbols, see figure 1):

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner	p			rh	3H, P 3P				
II	outer inner	f	f, P	f f	f, H c, P	H c, P	2h, Q, 2P c, 3P	c P	c c, 2P	c, 4P 2P
III	outer inner middle	f	p, f f c		3p′, P′ 4p			c	3p c, 3p	
IV	outer		p		H	4H				

Length of female and male caudal ramus twice width, inner margin setuliferous. Three long, plumose setae on posterior margin, two shorter, plumose setae from outer posterior lateral margin, naked seta from inner posterior ventral surface (figsure 15*c*,*d*).

Remarks.—This species is distinct from other known species of the genus in the inner extension of the protopodite of the third thoracic leg. It is similar to *A. serratus* Shiino, 1954, in the possession of the lobate accessory structure on the maxillipeds and in the secondary, spinelike ramifications of the terminal spines of the first thoracic leg, although those of *A. serratus* are much more distinct than in this species.

Anuretes menehune was found with *A. serratus* on specimens of *Naso hexacanthus* (Bleeker), *A. menehune* usually on the dorsal and anal fins and *A. serratus* on the caudal fin. Although the two species do occur on the same host, the areas they occupy were not observed to overlap.

The name "menehune" is derived from the fabled Menehune tribes that supposedly inhabited the Hawaiian Islands. These people were a legendary race of small people, whose purported construction efforts can still be seen in parts of the Hawaiian Islands. The name is used in regard to the relatively small size of the specimens of this species.

Genus *Dentigryps* Wilson

Diagnosis.—Fourth thoracic leg-bearing segment and genital segment fused in female, covered by single, dorsal plate. Lunules absent, sternal furca present; fifth legs of female elongate, conical, spinelike processes protruding from genital segment.

Remarks.—The genus was established by Wilson (1913) on the characteristics presented by the female of *D. Curtus* Wilson, 1913, the type-species of the genus. With the description of the new species below, the second species known for the genus, the diagnosis has been modified slightly.

Dentigryps bifurcatus, new species

Figures 17*a–c,e–k,m–q*, 18*a–c,e,f*

Material.—Nonovigerous adult female (holotype, USNM 105094) taken by author from side of specimen of *Acanthurus olivaceous* Bloch and Schneider given to author by Mr. Spencer Tinker from collections of Honolulu Aquarium. Mature male (allotype, USNM 105095) collected by author from caudal fin of specimen of *Naso hexacanthus* (Bleeker) captured in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Mature female (paratype, USNM 105096) collected by Dr. John Randall from epidermis of specimen of *Acanthurus triostegus sandvicensis* Streets captured in unknown locality on Oahu, Hawaii.

Measurements.—Holotype female: Length from anterior end to posterior end of caudal rami, excluding setae, 3.50 mm. Greatest length of cephalothorax, including frontal region, 2.44 mm.; greatest width, excluding marginal flanges, 2.30 mm. Greatest length of fused fourth thoracic leg-bearing segment and genital segment 0.70 mm.; greatest width of genital segment 1.19 mm.; length of left genital segment spine 0.78 mm. Tip of right spine broken.

Allotype male: Length from anterior end to posterior end of caudal rami, excluding setae, 1.97 mm. Greatest length of cephalothorax, including frontal region, 1.48 mm.; greatest width, excluding marginal flanges, 1.48 mm. Greatest length of fourth thoracic leg-bearing segment and genital segment, excluding sixth leg projections, 0.50 mm. (measurement taken on ventral surface); greatest width of genital segment 0.39 mm. Length of projecting fifth legs, excluding setae, 0.18 mm.

Paratype female: Length from anterior end to posterior end of caudal rami, excluding setae, 2.85 mm. Greatest length of cephalothorax, including frontal region, 2.07 mm.; greatest width, excluding marginal flanges, 1.93 mm. Greatest length of fused fourth thoracic

leg-bearing segment and genital segment 0.59 mm.; greatest width of genital segment 1.07 mm.; length of genital segment spines 0.66 mm.

DESCRIPTION.—Body of female with large, yellowish blotches in irregular pattern in alcohol; eye spots yellowish orange. Body of male yellowish in alcohol, with red spots scattered over surface; eyes as in female.

Cephalothorax of holotype female specimen ovoid, frontal region small, with thin, membranous flange along anterior margin; frontal region separated from cephalothorax by distinct, trilobed groove, median lobe much larger than lateral lobes. Lateral margins of cephalothorax with narrow, membranous flange. Posterior sinuses distinct, U-shaped, with two small, membranous flaps attached along lateral and anterior margins, one extending ventrally, other dorsally. Inner margin of posterior sinuses continuous with posterior lateral and posterior margins of median cephalothoracic region. Median cephalothoracic region extending slightly posterior to posterior lateral extensions of lateral cephalothoracic regions; middle of posterior margin slightly concave. Dorsal grooves of cephalothorax distinct, H-shaped; anterior portion of grooves terminating blindly posterior to eyes, cross groove, in middle of cephalothorax, curving anteriorly, not as distinct as longitudinal grooves. Lateral strengthening regions extending from just anterior to junction of cross and longitudinal grooves laterally and posteriorly, terminating just inside lateral margins of cephalothorax. Eyes small, situated in anterior third of cephalothorax, inner margins touching on median longitudinal axis of body (fig. 17*a*).

Fourth thoracic leg-bearing segment and genital segment fused in female, covered by single, dorsal plate. Fourth thoracic leg-bearing segment more distinct than in *D. curtus*, genital segment not beginning under posterior portion of cephalothorax as in *D. curtus* but slightly behind it. Genital segment expanded, lateral areas broadly rounded, middle of posterior margin concave, not convex as in *D. curtus*, posterior lateral margins without single, small, pointed protrusion present in *D. curtus* (figs. 17*c*,*d*). Fifth legs visible as long, acuminate, unjointed, spinelike projections from ventral posterior lateral surface of genital segment. Spinelike projection with three small, plumose setules, one on proximal lateral surface, one on ventral medial surface, one on ventral distal surface (figs. 17*c*,*d*).

Abdomen of female one-segmented, attached to posterior surface of genital segment, not ventral surface as in *D. curtus*. Width of abdomen approximately same as length. Abdomen without posterior lateral extensions found in *D. curtus* (figs. 17*c*,*d*).

Cephalothorax of allotype male similar to that of female except frontal region with flatter anterior margin. Region of third thoracic

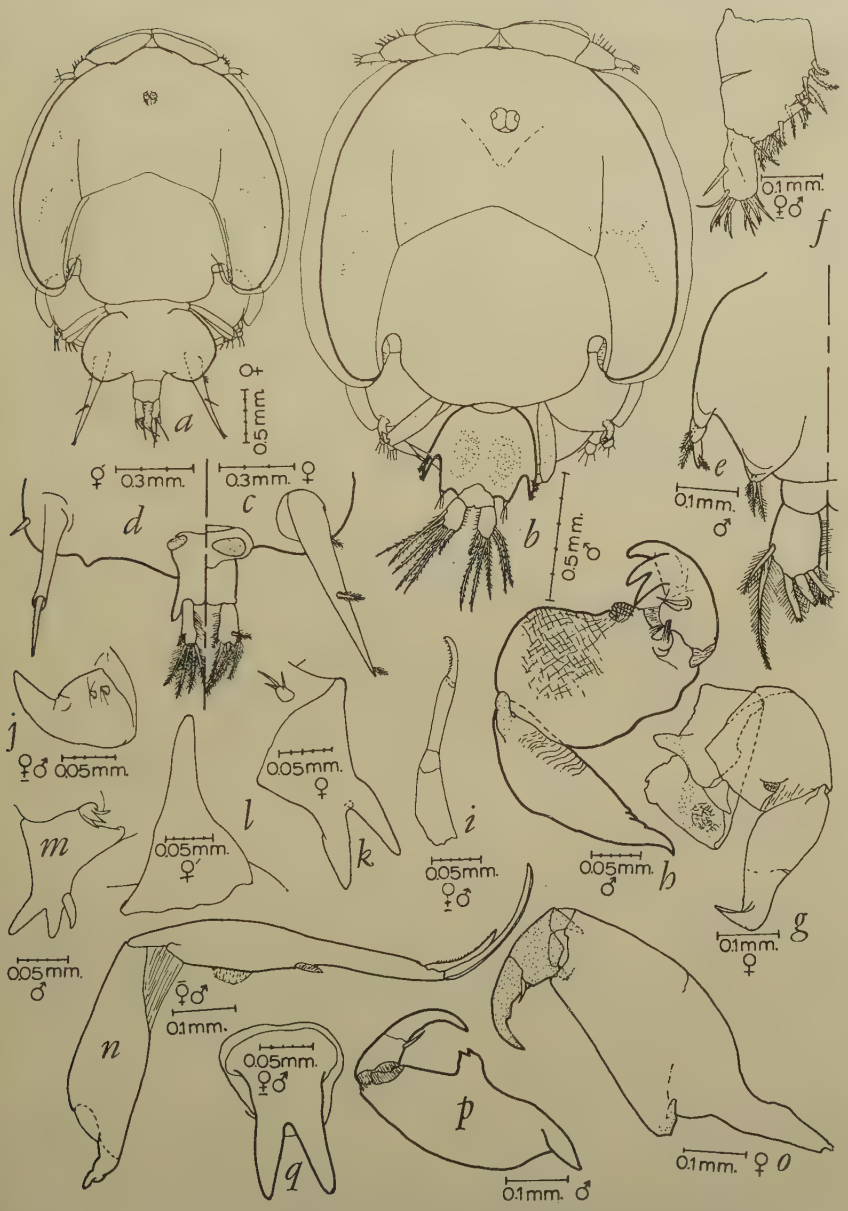

FIGURE 17.—*Dentigryps bifurcatus*, new species (holotype female, allotype male): *a*, dorsal view of female; *b*, dorsal view of male; *c*, ventral view of posterior end of genital segment, fifth leg, abdomen, and caudal ramus of female; (*d*, ventral view of posterior end of genital segment, fifth leg, abdomen, and caudal ramus of female specimen of *D. curtus*); *e*, ventral view of posterior end of genital segment, fifth and sixth legs, abdomen, and caudal ramus of male; *f*, antennule; *g*, female second antenna; *h*, male second antenna; *i*, mandible; *j*, postantennal process; *k*, postoral process of female; (*l*, postoral process of female specimen of *D. curtus*); *m*, postoral process of male; *n*, maxilla; *o*, maxilliped of female; *p*, maxilliped of male; *q*, sternal furca.

leg-bearing segment of thorax, contained in cephalothorax, extended over fourth thoracic leg-bearing segment. Fourth thoracic leg-bearing segment partially visible dorsally, separated from genital segment by distinct line of division; fourth thoracic leg-bearing segment and genital segment not covered by single, dorsal plate as in female. Fifth legs visible as conical projections of lateral margins of genital segment, projections appearing as series of three overlapping, lappet-like processes, each bearing single, terminal, plumose seta. Sixth legs visible as conical projections of posterior lateral margins of genital segment, lappet-like processes visible on fifth legs also present on sixth though not as distinct; sixth legs with three terminal, plumose setules (figs. 17*b*,*e*).

Antennule of male and female two-segmented, excluding frontal plate, attached to ventral surface of both cephalothorax and frontal region just medial to lateral margins of frontal region. First segment broad proximally, tapered on anterior margin to narrow distal end; greatest length one and one-fourth times greatest width. Anterior margin of first segment with fifteeen plumose setae. Second segment slightly more than half length of first, with naked seta on middle of posterior margin and 13 naked setae from rounded distal end (fig. 17*f*).

Second antenna of holotype female three-segmented, attached posterior and medial to antennule base. First segment short, broad, forming articular surface for second segment; with triangular, posteriorly directed process. Second segment well developed, greatest width equal to greatest length, with small adhesion pad on inner distal surface. Second segment with several small, heavily chitinized depressions on distal margin serving as articular surfaces for third segment. Third segment with terminal, clawlike process; division between segment and process indistinct. Terminal process curved sharply inwards distally. Length of third segment and terminal process greater than that of second segment; third segment without accessory processes (fig. 17*g*).

Second antenna of allotype male three-segmented; first segment long, narrow proximally, expanded medially, tapered distally; distal end with projecting, lobate articular process, without posteriorly projecting process of female. First segment with adhesion surface on outer distal half of segment. Second segment strongly developed, swollen proximally, narrow distally. Inner surface of second segment forming adhesion surface proximally; with small, swollen adhesion surface projecting from inner distal surface; both adhesion surfaces on inner surface connected by irregular ridges. Third segment short, with compound terminal process consisting of simple, curved, spinelike structure with bifurcate process fused to anterior lateral

surface of terminal process. Third segment with single, spinelike accessory process at indistinct junction of terminal process and segment (fig. 17*h*).

Mandible of female and male four-parted. First part with broad base, tapered regularly to slightly narrower distal end; second part short, distinctly tapered to junction of third part. Third part elongate, length slightly less than combined lengths of first two parts; fourth part slightly more than half length of third, curving inward, bearing 11 toothlike denticulations on inner margin (fig. 17*i*).

Postantennal process of female and male simple, spinelike process attached just lateral, and slightly posterior to, base of second antenna. Spinelike process curved posteriorly, terminating in blunt tip, bearing two minute nodules on inner proximal surface, proximal nodule with two long setules, distal with three (fig. 17*j*).

Postoral process of paratype female specimen bifurcate, attached just lateral to base of mouth cone (process broken in holotype). Postoral process of *D. curtus* simple, spinelike process, not bifurcate as in *D. bifurcatus* (fig. 17*l*). Distance across base of bifurcate process greater than distance between tips, length of tines approximately one-third length of process; single, slight protrusion present just proximal to apex of bifurcation. Single, lobate process present just anterior to base of spine, with three setules from distal surface (fig. 17*k*).

Postoral process of male similar to that of female except with large, finger-like protrusion on inner margin of bifurcate process (fig. 17*m*).

Maxilla of female and male two-segmented, attached slightly lateral and posterior to postoral process. Proximal segment strongly developed, broader at base than at distal end, with articular process forming extension of inner proximal surface. Distal end of first segment flat. Second segment elongate, greatest length about one and one-fourth times that of first segment; inner proximal surface irregular, proximal end articulating with flat distal end of first segment. Proximal half of second segment slightly swollen, both margins convex, with fine, membranous flap on inner margin. Spine with attached membrane present on middle of inner margin of segment. Second segment terminated by two curved, spinelike processes, inner almost twice length of outer, with fine membrane along inner margin. Outer spinelike process on distal end of second segment with frilled membrane along outer margin (fig. 17*n*).

Maxilliped of female two-segmented, attached slightly posterior and medial to maxilla. First segment well developed, with long articular process extending from outer proximal portion of segment. Distal margin with several heavily chitinized surfaces serving as articular surfaces for second segment. Second segment short, forming, with

well-developed terminal process, clawlike structure. Distal end of terminal process strongly curved; division between terminal process and second segment distinct, segment with small, spinelike accessory process on inner margin at junction of segment and terminal process. Terminal process of second segment with several small, rounded swellings on inner median surface (fig. 17*o*).

Maxilliped of male similar to that of female except with large protrusion of middle of inner margin to receive distal end of terminal process of second segment when segment flexed. Articular process on proximal end of first segment shorter than that of female (fig. 17*p*).

Sternal furca of female and male situated between, and slightly posterior to, bases of maxillipeds. Greatest width of base of process slightly more than distance across tips of tines; tines directed slightly outward from apex of bifurcation, terminating in blunt tips. Bifurcation extending almost half length of furcal process (fig. 17*q*).

First thoracic leg biramous though endopodite present only as small, finger-like projection at junction of protopodite and exopodite. Protopodite one-segmented, with small projection of outer proximal end forming articular surface. Distal margin of protopodite irregular, with single, plumose setule on outer corner. Exopodite two-segmented, first segment saddle-shaped, with single spinule and large, rounded articular process on outer distal margin. First segment of exopodite of *D. curtus* much longer, with spinule on outer distal margin and setules on inner margin as in *D. bifurcatus*. Second segment of exopodite short, less than half length of first, with three spines and one small, plumose seta on distal surface. Innermost and medial terminal spines with row of fine setules on inner margin and slight concave depression of inner distal surface across which fine membrane stretches (fig. 18*a*).

Second thoracic leg biramous. Protopodite two-segmented; first segment short, slightly more than half length of second segment, with bilobed proximal end. Exopodite three-segmented; first segment longer than combined lengths of second and third, with small lobate process on proximal surface; process also present on *D. curtus* but not reported by either Wilson (1913) or Yeatman (1957). First segment with strongly developed terminal spine on outer corner, spine with row of minute setules along inner margin. Second segment with single spine, spine slightly shorter than that of first segment. Third segment with two spines, proximal extending at slight angle to margin of segment (not visible in figure). Endopodite three-segmented, second segment irregular, greatest length approximately equal to that of first and third segments combined (fig. 18*b*).

Third thoracic leg biramous. Protopodite one-segmented, forming broad, flat, platelike structure. Exopodite three-segmented, with

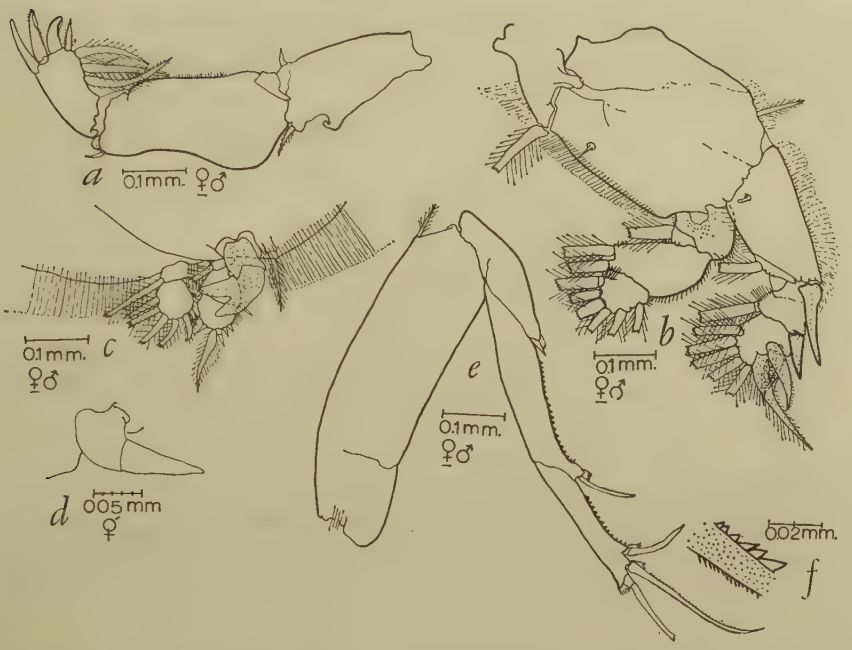

FIGURE 18.—*Dentigryps bifurcatus*, new species (holotype female, allotype male): *a*, first thoracic leg; *b*, second thoracic leg; *c*, third thoracic leg; (*d*, third thoracic leg exopodite process of *D. curtus*); *e*, fourth thoracic leg; *f*, portion of denticulated median terminal spine of fourth thoracic leg.

large, inwardly curved, bifurcate process at junction of protopodite and exopodite. Process of exopodite of third thoracic leg of *D. curtus* simple, not bifurcate (fig. 18*d*). First segment of exopodite small, flattened, second and third segments combined, forming obovate structure. Endopodite two-segmented; first segment broad, short; second segment arising from distal lateral surface of first, length slightly greater than width, segment broadly rounded (fig. 18*c*).

Fourth thoracic leg uniramous, four-segmented. Protopodite one-segmented, length slightly less than combined lengths of all three exopodite segments. Protopodite with single plumose setule from outer distal corner. Exopodite three-segmented; first segment short, with single, short, simple spine from distal end, spine encircled by frilled membrane. Second segment with row of toothlike denticulations along outer margin, with simple spine from slightly swollen distal end, spine encircled by frilled membrane. Third segment with toothlike denticulations along outer margin as in second, distal end with three spines, outermost short, simple, without denticulations; middle spine longer, margins heavily denticulated (fig. 18*f*); inner spine long, lightly denticulated. Three terminal spines encircled by frilled membrane (fig. 18*e*).

The character of the membranes, spines, and setae on the thoracic legs is given below (for explanation of symbols, see figure 1):

Leg	Margin	Sternal plate	Protopodite		Exopodite			Endopodite		
			1	2	1	2	3	1	2	3
I	outer inner		p		rh c	3H, P 3P				
II	outer	f		f, p	f, H	H	2H, Q, 2P	c	c	c, 3P
	inner		f, P	f, s	c, P	c, P	c, 3P	c, P	c, 2P	c, 3P
III	outer inner	f	f, P P, f		H′, c P	c, p′ c, P	c, 3p′, P c, 3P	c P	c, 3P c, 3P	
IV	outer		p		h	H	H, 2dH			

Caudal rami of female and male attached to posterior surface of abdomen. Width slightly more than half length, greater in male than in female. Inner margin setuliferous; distal end with six plumose setae, three from distal margin, one from inner distal corner, one from outer distal corner, one from ventral surface. Setae from distal margin long, from lateral and ventral surfaces short.

Remarks.—This is the second known species of the genus. The first, *D. curtus*, is known only from the tropical and subtropical western North Atlantic. The two species possess general similarities but differ in characteristics such as thoracic leg armature and the shape of the various processes and accessory structures. A list of the major differences between *D. curtus* and *D. bifurcatus* is given below:

D. curtus (female; male unknown)

1. Posterior end of cephalothorax covering fourth thoracic leg-bearing segment and part of genital segment.
2. Posterior end of genital segment almost flat, with two small protrusions of posterior lateral margin.
3. Genital segment spines (fifth legs) jointed, two-parted.
4. Abdomen attached to ventral surface of genital segment, with small lappet-like protrusion of outer distal corner.
5. Postoral process a simple spinelike process.
6. Third thoracic leg exopodite process simple.

D. bifurcatus (female)

1. Part of fourth thoracic leg-bearing segment visible behind cephalothorax.
2. Posterior end of genital segment bilobed, without protrusions.
3. Genital segment spines (fifth legs) not jointed.
4. Abdomen attached to posterior surface of genital segment, without small lappet-like protrusion of outer distal corner.
5. Postoral process bifurcate.
6. Third thoracic leg exopodite process bifurcate.

The name "bifurcatus" applies to the bifurcate condition of the postoral process and of the third thoracic leg exopodite process.

Family Pandaridae

Genus *Nesippus* Heller, 1865

DIAGNOSIS.—Cephalothorax consisting of cephalon, maxilliped, and first thoracic leg-bearing segments; second, third, and fourth thoracic leg-bearing segments free. Cephalothorax typically longer than wide, with posteriorly projecting lateral regions. Male with or without conspicilla placed slightly anterior and lateral to paired eyes. Second thoracic leg-bearing segment with lateral and posterior lateral projecting lobes. Abdomen small, one-segmented. Distal region of maxillipeds swollen, terminal process knoblike, forceps-like or flattened and clawlike. All thoracic legs biramous; rami of legs 1–3 two-segmented, fourth leg rami one-segmented.

REMARKS.—The diagnosis is mainly from Wilson (1907) with modification based on the characteristics of the species described subsequent to his publication. The adult female and male of this genus are found primarily on elasmobranch hosts, but the adult male also is taken in the plankton.

The function of the "conspicilla," Dana's term for the two transparent projections on the dorsal surface in the region of the eyes of some males, is not known. Dana (1853) indicates that they are distinct from the cephalothorax and are of a "brittle, though rather hard" nature.

Nesippus costatus? Wilson

FIGURES 19*a–e*, 20*a–s*, 21*a–p*

N. costatus Wilson, 1924, pp. 213–214, pl. 20.

TYPE HOST.—"A nine-foot shark."

TYPE LOCALITY.—Galapagos Islands.

MATERIAL.—Immature male taken by author from cyst on dorsal fin of specimen of *Acanthurus triostegus sandvicensis* Streets captured by U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, at Midway Island (USNM 105176). Immature male taken by author from cyst on anal fin of specimen of *Acanthurus nigroris* Cuvier and Valenciennes captured in fish trap in Kaneohe Bay, Oahu, Hawaii, by Lester Zukeran (USNM 105177). Immature male from cyst on anal fin of specimen of *Acanthurus xanthopterus* Cuvier and Valenciennes captured in fish trap in Kaneohe Bay, Oahu, Hawaii, by Lester Zukeran (USNM 105178). Male specimen collected by Dr. John Randall from epidermis of specimen of *Acanthurus triostegus sandvicensis* Streets from an unknown locality, probably on Oahu,

Hawaii (USNM 105179). Immature male and its exuvium taken by Carolyn Lewis from cyst on pectoral fin of specimen of *Diodon holocanthus* Linnaeus donated by Honolulu Aquarium (USNM 105180). Immature male taken by author from cyst on pectoral fin of specimen of *Diodon holocanthus* Linnaeus donated by Honolulu Aquarium (USNM 105181). One cyst containing immature male taken by author from pectoral fin of specimen of *Ctenochaetus strigosus* (Bennett) donated by Honolulu Aquarium (USNM 105182). Immature male taken by author from cyst on dorsal fin of specimen of *Acanthurus triostegus sandvicensis* Streets speared by N. Ferris in Kaneohe Bay, Oahu, Hawaii (USNM 105183). Immature male taken by author from cyst on dorsal fin of specimen of *Scarus* species speared by author in Hanauma Bay, Oahu, Hawaii (USNM 105184).

Additional specimens, not used in the following description, were taken from cysts on fins of specimens of the following families of fishes: Labridae, Pomacentridae, Zanclidae.

Measurements.—Early encysted stage (two specimens): Length from anterior end of body to posterior end of caudal rami, excluding setae, 1.90 and 2.58 mm. Greatest length of cephalothorax, including frontal region, 0.82 and 1.23 mm.; greatest width 1.03 and 1.31 mm. Greatest length of free thoracic leg-bearing segments, genital segment, abdomen, and caudal rami, excluding setae, 1.11 and 1.60 mm. Greatest length of genital segment 0.18 and 0.34 mm.; greatest width of genital segment 0.36 and 0.42 mm. Greatest length of abdomen 0.13 and 0.17 mm. Greatest length of caudal rami, excluding setae, 0.25 mm.

Late encysted and recently excysted stage (five encysted specimens, one recently excysted specimen): Average length from anterior end of body to posterior end of caudal rami, excluding setae, 3.40 mm.; range 2.94–4.05 mm. Average of greatest length of cephalothorax, including frontal region, 2.02 mm.; range 1.84–2.12 mm.; average of greatest width 2.02 mm.; range 1.66–2.21 mm. Average of greatest length of free thoracic leg-bearing segments, genital segment, abdomen, and caudal rami, excluding setae, 1.93 mm.; range 1.47–2.30 mm. Average of greatest length of genital segment 0.49 mm.; range 0.42–0.59 mm.; average of greatest width 0.73 mm.; range 0.64–0.82 mm. Average of greatest length of abdomen and caudal rami, excluding setae, 0.24 mm.; range 0.15–0.29 mm. Average of greatest length of abdomen 0.21 mm.; range 0.17–0.27 mm. Average of greatest length of caudal rami, excluding setae, 0.18 mm.; range 0.15–0.21 mm.

Description.—Color of all stages light brown to brownish yellow in life, with no distinct color pattern. Conspicilla transparent, distinct on dorsal surface. Eyes reddish brown. Single excysted speci-

men with light reddish area around posterior medial margin of conspicilla in alcohol.

Cyst of general ovoid shape, appearing to be formed of epidermis of host; found only on fins of host, usually parallel to fin rays. Small opening present on end of cyst, caudal rami setae visible protruding through opening. Color of cyst similar to that of host (fig. 19*a*).

Since the complete life history of this copepod has not been worked out, the stages passed within the cyst have been divided arbitrarily into two groups: the early encysted stage; and the late encysted and recently excysted stage. Cephalothorax of early encysted forms orbicular, frontal region distinct in older specimen, indistinct in younger. Frontal region in older specimen with deep median groove; younger specimen without groove, middle of anterior margin convex. Anterior surface of frontal region with indistinct transverse ridges in older specimen, not visible in younger. Division between frontal region and cephalothorax incomplete in both specimens. Older specimen with distinctly raised, anteriorly bilobed surface at region of junction of frontal region and cephalothorax. Lateral margins of cephalothorax without marginal flange; posterior sinuses of younger specimen slight, apically pointed indentations, shallow but distinct V-shaped sinuses present in older specimens. Posterior margin of cephalothorax, medial to posterior sinuses, trilobed; lateral areas extending further posteriorly than trilobed median portion. Longitudinal grooves of cephalothorax present in younger specimens as indistinct grooves extending from apex of posterior sinuses anteriorly, terminating blindly in posterior fourth of cephalothorax. Grooves of older specimen extending from apex of posterior sinuses anteriorly to just behind eyes, then turning laterally, terminating blindly medial to lateral margins. Older specimen with indistinct medial, longitudinal groove extending from region behind eyes to posterior surface of genital segment. Eyes in both younger and older early encysted forms distinct, consisting of pair of large, circular eyes with inner margins separated, one on either side of median longitudinal axis of body, and small, median, third eye between, and immediately posterior to, paired eyes. Conspicilla indistinct in both specimens, appearing as slightly roughened region anterior and lateral to eyes (figs. 19*b*,*c*).

Second, third, and fourth thoracic leg-bearing segments of early encysted forms free, successively decreasing in size. Second thoracic leg-bearing segment of younger specimen three times as wide as long; width of segment in older specimens slightly more than twice length. Lateral margins of second thoracic leg-bearing segment of younger specimen broadly rounded, of older specimen concave in anterior region, flaring in convex curve posteriorly. Posterior margin of second

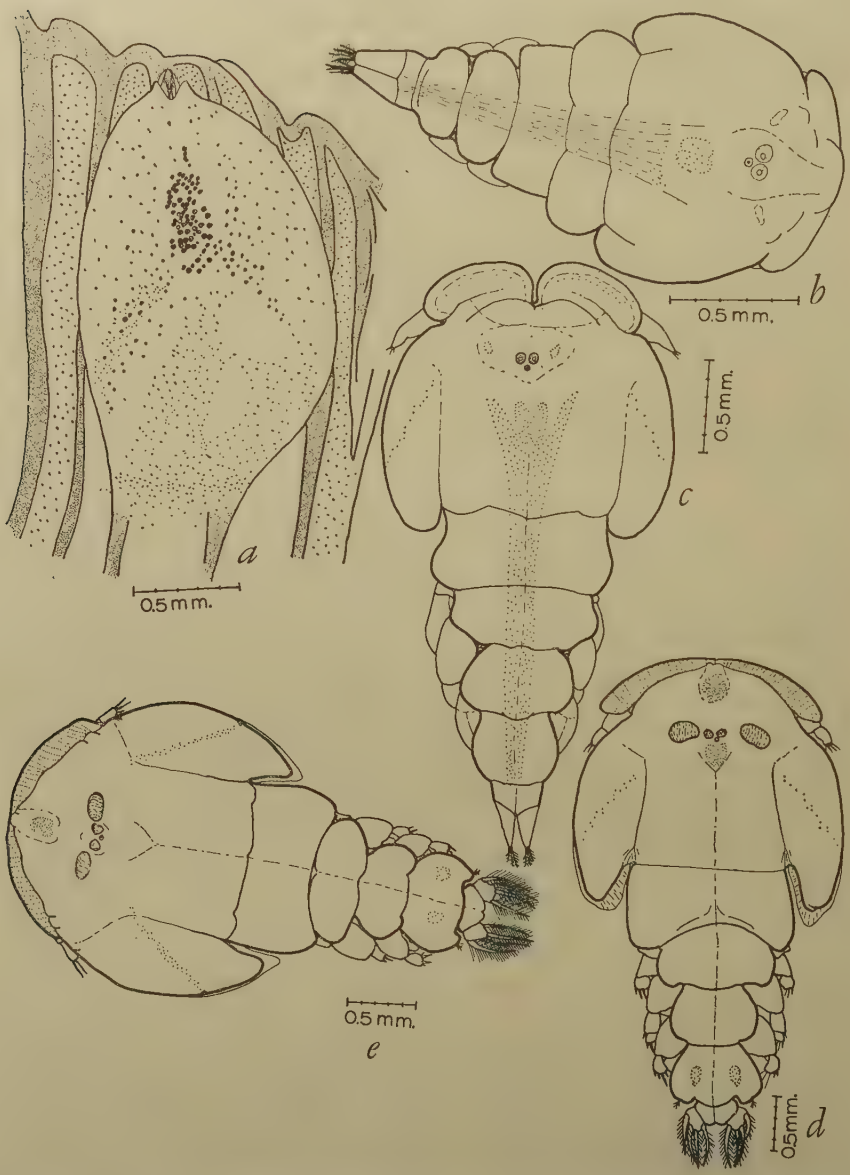

FIGURE 19.—*Nesippus costatus?* Wilson, 1924: *a*, cyst on fin of teleost host; *b*, dorsal view of younger early encysted specimen; *c*, dorsal view of older early encysted specimen; *d*, dorsal view of late encysted specimen; *e*, dorsal view of recently excysted specimen.

thoracic leg-bearing segment irregular in younger specimen, regularly concave in older. Third thoracic leg-bearing segment almost rectangular in younger specimen though tapering slightly posteriorly; greatest width almost three times greatest length; posterior margin concave.

Lateral margins of third thoracic leg-bearing segment concave in anterior portion of older specimen, convex in posterior portion, curving sharply inward to junction of fourth thoracic leg-bearing segment. Greatest width of third thoracic leg-bearing segment in older specimen slightly more than twice length. Lateral margins of fourth thoracic leg-bearing segment of younger specimen broadly rounded, greatest width slightly less than twice greatest length. Fourth thoracic leg-bearing segment in older specimen ovoid, greatest length about three-fourths greatest width.

Width of genital segment in early encysted specimens slightly less than width of fourth thoracic leg-bearing segment. Lateral margins broadly rounded in anterior three-fourths of segment in younger specimen, curving sharply inward posteriorly to slight projection of medial two-thirds of segment; greatest length about two-thirds greatest width. Lateral margins of segment in older specimen flatly convex, greatest length slightly more than two-thirds greatest width. Abdomen short, one-segmented; slightly longer in older than in younger specimen. Greatest length of abdomen approximately half length of genital segment (figs. 20*a*,*b*).

Cephalothorax of late encysted and recently excysted forms ovoid. Frontal region distinct, narrow, anterior margin flatly rounded; frontal region with distinct transverse ridges across entire surface though not as distinct on posterior as on anterior surface. Division between frontal region and cephalothorax distinct, complete; small projecting lobe in middle of margin separating frontal plates in excysted specimen present but not reaching anterior margin in late encysted specimens, though plates separated by distinct groove extending from anterior projecting lobe to anterior margin. Lateral margins of cephalothorax with very thin flange on anterior portion, broader on posterior portion, extending around posterior extensions of lateral regions into posterior sinuses. Posterior sinuses distinct, slender, V-shaped. Posterior sinuses extending anteriorly to junction of cephalothorax and second thoracic leg-bearing segment; posterior extensions of lateral cephalothoracic regions projecting to middle of second thoracic leg-bearing segment. Median posterior margin slightly irregular, extending between apices of posterior sinuses. Longitudinal grooves on dorsal surface of cephalothorax distinct posteriorly, extending from apex of posterior sinuses anteriorly, becoming indistinct lateral and posterior to eyes though discontinuous extensions visible curving anteriorly and laterally, extending to proximity of lateral margin. Indistinct, discontinuous median longitudinal groove present, extending posteriorly to anus from V-shaped, indistinct groove posterior to eyes. Eyes distinct, consisting of pair of oval eyes, one on either side of median longitudinal axis of body, with inner margins

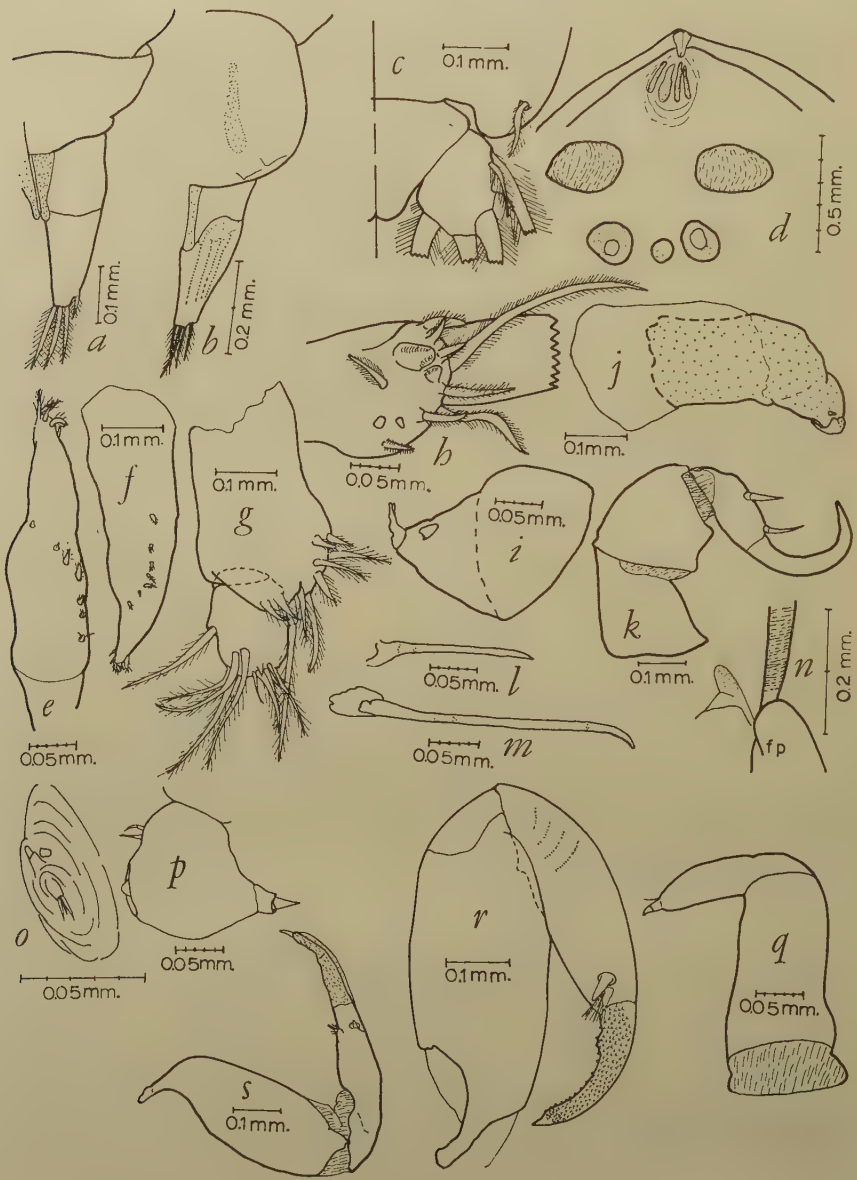

FIGURE 20.—*Nesippus costatus?* Wilson, 1924: *a*, ventral view of genital segment, abdomen, and caudal ramus of younger early encysted specimen; *b*, same, of older early encysted specimen; *c*, ventral view of posterior portion of genital segment, fifth legs, abdomen, and caudal ramus of late encysted and recently excysted specimens; *d*, dorsal view of anterior end of late encysted and recently excysted specimens showing eyes, conspicilla, and frontal organ; *e*, antennule of younger early encysted specimen; *f*, antennule of older early encysted specimen; *g*, antennule of late encysted specimen; *h*, distal end of first segment of antennule of recently excysted specimen; *i*, second antenna of

separated; third, median eye present between paired eyes (fig. 20*d*). Conspicilla large, distinct, oblong; projecting from dorsal surface of cephalothorax just anterior and lateral to paired eyes. Surface of conspicilla ridged, similar in appearance to adhesion pads of many pandarids (fig. 19*d*).

Second thoracic leg-bearing segment of late encysted and recently excysted specimens larger than third or fourth thoracic leg-bearing segment; lateral margins almost parallel, anterior half forming inner margin of posterior sinuses, posterior lateral margins curving smoothly inward, posterior lateral surfaces projecting slightly past anterior end of third thoracic leg-bearing segment. Posterior margin of second thoracic leg-bearing segment concave; greatest length of segment slightly more than half greatest width. Third thoracic leg-bearing segment with broadly rounded lateral margins, greatest length slightly more than half greatest width in encysted forms, slightly less in excysted form. Posterior lateral margins of third thoracic leg-bearing segment forming small, posteriorly projecting lobes in encysted form, middle of posterior margin slightly convex; posterior margin of recently excysted form evenly curved except for slight concavity in middle. Fourth thoracic leg-bearing segment narrower than third, greatest length approximately two-thirds greatest width; lateral margins evenly curved. Posterior lateral corners of fourth thoracic leg-bearing segment of excysted form forming small, posteriorly projecting lobes, encysted form without lobes.

Genital segment of late encysted and recently excysted forms of general ovoid shape, slightly wider than fourth thoracic leg-bearing segment, greatest length approximately two-thirds greatest width; internal spermatophores indistinctly visible in encysted, distinctly visible in excysted specimens. Lateral margins broadly curved; posterior lateral surfaces of genital segment forming small, posteriorly projecting lobes with fifth legs projecting from apex as single plumose seta arising from ventral surface. Middle of posterior margin convex, projecting slightly over anterior surface of abdomen. Abdomen short, one-segmented, greatest length slightly less than greatest width; widest point in anterior median region of segment, tapered to narrower anterior and posterior ends of segment. Posterior margin of abdomen indented at anus (fig. 20*c*).

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younger early encysted specimen; *j*, second antenna of older early encysted specimen; *k*, second antenna of late encysted and recently excysted specimens; *l*, mandible of early encysted specimens; *m*, mandible of late encysted and recently excysted specimens; *n*, adhesion pad on late encysted and recently excysted specimens (fr=frontal region); *o*, postoral process of early encysted specimens; *p*, postoral process of late encysted and recently excysted specimens; *q*, maxilla of early encysted specimens; *r*, maxilla of late encysted specimen; *s*, maxilla of recently excysted specimen.

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Antennule of early encysted forms one-segmented, attached to anterior ventral surface in frontal region. Single segment irregular in shape, flaccid, tapered to round tip bearing six small, plumose setae. Middle of antennule with irregular row of six setae, each with several setules. Two segments of late encysted antennule visible inside early encysted antennule (figs. 20*e,f*).

Antennule of late encysted and recently excysted forms two-segmented. First segment two and a half times length of second in late encysted specimens, approximately two times length of second segment in recently excysted specimen. Lateral margins almost parallel in proximal region, with knoblike convexity of anterior surface in distal region. First segment with eight short, plumose setae, one long plumose seta, two large and two small lobate protrusions, all from knoblike convexity (fig. 20*h*).

Second segment of excysted specimen slightly longer than that of encysted, both with two plumose setae on distal portion of posterior margin, three plumose setae from posterior distal surface, and six naked setae from anterior distal surface. Setae and lobes on excysted specimen developed to slightly greater extent than on encysted specimens (figs. 20*g,h*).

Second antenna of early encysted specimens two-segmented, attached just posterior to base of antennule. Second antenna consisting of large, conical first segment and small, irregular second segment. First segment of older specimen more slender than that of younger, with indication of segmentation visible inside appendage but not externally; both older and younger specimens with small, tubercular projection from posterior distal surface. Distal segment of older specimen recurved more than that of younger; younger specimen with minute, lobate projection from inner distal surface of segment; older specimen without lobate projection but with minute, irregular extension of distal surface (figs. 20*i,j*).

Second antenna of older encysted and recently excysted specimens three-segmented, attached slightly posterior and medial to antennule base. First segment short, broad, width and length about equal, lateral margins irregular, with well-developed articular surface on outer proximal edge articulating with concave depression of segment-like extension of ventral surface of cephalothorax. Inner distal surface of first segment projecting beyond remaining distal surface as broad articular surface, fitting in heavily chitinized depression on outer proximal surface of second segment. Second segment strongly developed, slightly longer than wide, longer than first segment; lateral margins somewhat irregular, inner margin convex. Inner distal surface of second segment projecting as rodlike structure, articulating with knoblike process on third segment. Third segment and terminal

process falciform, more so in excysted than in encysted specimens. Length of third segment and terminal process slightly shorter than combined lengths of first two segments. Third segment with two spinelike accessory processes on inner surface, one on proximal, second on distal portions of segment. Division between terminal process and segment distinct (fig. 20*k*).

Mandible of early encysted, late encysted and recently excysted specimens four-parted. Mandible of late encysted and recently excysted specimens slightly longer than that of early encysted. First part of mandible of all specimens broader proximally than distally, with even taper to junction of second part. Second part short, slightly more than half length of first part in early encysted specimens, less than half in late encysted and recently excysted specimens; with little taper to junction of third part. Third part elongate, almost twice length of first part, tapered slightly in younger specimens, not in older. Fourth part short, slightly longer than second part, curved inward slightly at distal end, with distinct, toothlike denticulations along inner margin of older specimens, denticulations not visible in younger specimens (figs. 20*l*,*m*).

Postoral process of early encysted specimens mound-shaped swelling adjacent to base of mouth cone, with two small, lobate protrusions on anterior surface and single, small, apical projection bearing three setules on posterior distal surface (fig. 20*o*).

Postoral process of late encysted and recently excysted specimens bulbous protrusion adjacent to base of mouth cone. Distal surface of process larger than proximal, with single spine projecting from posterior distal surface, two setules from anterior proximal surface and single knob from anterior distal surface, arising from slight depression in surface. Wilson (1924) notes three setules instead of two from the anterior proximal surface and does not mention the spine found on the presently described specimens (fig. 20*p*).

Maxilla of early encysted forms two-segmented, both segments flaccid. First segment with almost parallel lateral margins, no articular surfaces visible. Second segment tapered to blunt tip in younger specimen, rounded but sharper tip in older specimen; length of segment about half that of first segment in younger specimen, two-thirds that of first segment in older specimen. Distal end of second segment in both specimens tipped by small, pointed protrusion; younger specimen with additional, setule-like structure on outer distal corner, structure not present in older specimen (fig. 20*q*).

Maxilla of late encysted specimens two-segmented. First segment strongly developed, with long projection of middle of proximal surface as articular surface. Lateral margins of first segment flatly convex; middle of distal surface projecting as articular surface, middle of distal

projection heavily chitinized, articulating with small concavity on inner proximal surface of second segment. Second segment with terminal process slightly shorter than first segment, including proximal extension of first segment. Second segment tapered slightly to blunt distal end, tipped by long, slightly curved, dactyliform process with small-pointed protrusion from tip of process. Terminal process of late encysted form sheathed with membranous structure covered with minute, toothlike denticulations; recently excysted specimen also with sheathed process but denticulations replaced by minute tubercles. Distal end of segment, just proximal to base of terminal process, with two accessory processes on anterior margin: first a short, sharply tipped process; second membranous, irregularly shaped process surrounded by tuft of setules (figs. 20*r*,*s*).

Maxilliped of early encysted form two-segmented, attached posterior to base of maxilla. First segment in younger specimen narrower in proximal than in distal regions, distal region overlapping proximal region giving two-parted appearance to segment. Second segment of younger specimen short, less than one-fourth length of first segment; segment and terminal process continuous, terminal process flaccid, forming slender projection of segment. First segment of older early encysted specimen similar to that of younger but distal portion larger, greatly swollen, with adhesion pad on inner distal surface. Second segment of older specimen similar to that of younger though terminal process short but distinct clawlike process fitting into adhesion pad of first segment. Second segment of older specimen with accessory, spinelike process from inner surface just proximal to base of terminal process. Division between terminal process and segment in older specimen distinct (figs. 21*a*,*b*).

Maxilliped of late encysted and recently excysted specimens similar in general appearance to that of older early encysted specimen. Adhesion pad on inner distal surface of first segment with additional, knoblike process extending from distal margin. Second segment more strongly developed, heavily chitinized at articulation with first segment, with two accessory processes instead of one found in older early encysted specimen; terminal process not clawlike but rounded protuberance similar to that of adhesion pad of first segment and abutting with this process when second segment flexed (figs. 21*c*,*d*).

First thoracic leg of early encysted specimens biramous, both rami dactyliform, without external evidence of segmentation. Both protopodite and rami flaccid. Exopodite extending beyond distal margin of endopodite, with three spines in younger specimen, one from outer distal lateral surface, two from distal margin; four spines on older specimen, three as in younger specimen, from distal margin, fourth from inner distal lateral surface. Endopodite with three

minute, lobate projections from distal surface. Early encysted specimens with indistinct evidence of two-segmented exopodite and endopodite visible inside dactyliform rami (figs. 21*e*,*f*).

First thoracic leg of late encysted and recently excysted specimens biramous. Protopodite irregular in outline, with two plumose setae, one on either side of rami. Exopodite two-segmented; first segment longer than second, lateral margins irregularly convex, with single spine from outer distal lateral corner. Second segment with narrow proximal surface, wide distal surface; lateral and distal margins continuous. Endopodite two-segmented, both segments of approximately equal length. First segment slightly shorter than second, with convex lateral margins in encysted specimens, of rectangular shape in excysted specimen. Second segment with continuous distal and outer lateral margins (fig. 21*g*).

Second thoracic leg of early encysted specimens biramous, rami one-segmented. Both protopodite and rami flaccid; protopodite with minute projections on inner surface of younger specimen, plumose setule on older. Exopodite slightly longer than endopodite, tipped with four minute, lobate projections, one from each distal lateral surface, two from distal surface. Endopodite with single plumose setule from middle of inner margin, four minute, sharp projections from distal margin. Two-segmented exopodite and endopodite of late encysted specimens visible inside rami (figs. 21*h*,*i*).

Second thoracic leg of late encysted and recently excysted specimens biramous. Protopodite broad, length approximately three-fourths width, with single naked setule on distal margin next to outer lateral margin of exopodite and plumose seta on inner proximal margin. Exopodite two-segmented; first segment longer than second, narrower proximally than distally, outer surface with patch of short, hairlike projections giving fuzzy appearance to region. First segment with single spine on outer distal lateral margin. Second segment of exopodite orbicular, margins continuous, with three small, membrane-margined spines on outer lateral margin. Endopodite two-segmented; first segment slightly more than half length of second, second segment of general ovoid shape, lateral and distal margins distinct (fig. 21*j*).

Third thoracic legs of early encysted forms biramous, rami one-segmented. Protopodite and rami flaccid; protopodite of older specimen with single, plumose setule from inner proximal margin, with small, knoblike projection outside exopodite of younger specimen. Both rami of about equal length, exopodite of younger specimen with three plumose setules from distal margin, one from inner lateral margin and four minute, spinelike processes from distal outer margin. Exopodite of older specimen with three plumose setules from distal margin; one plumose setule and one minute plumose setule from outer

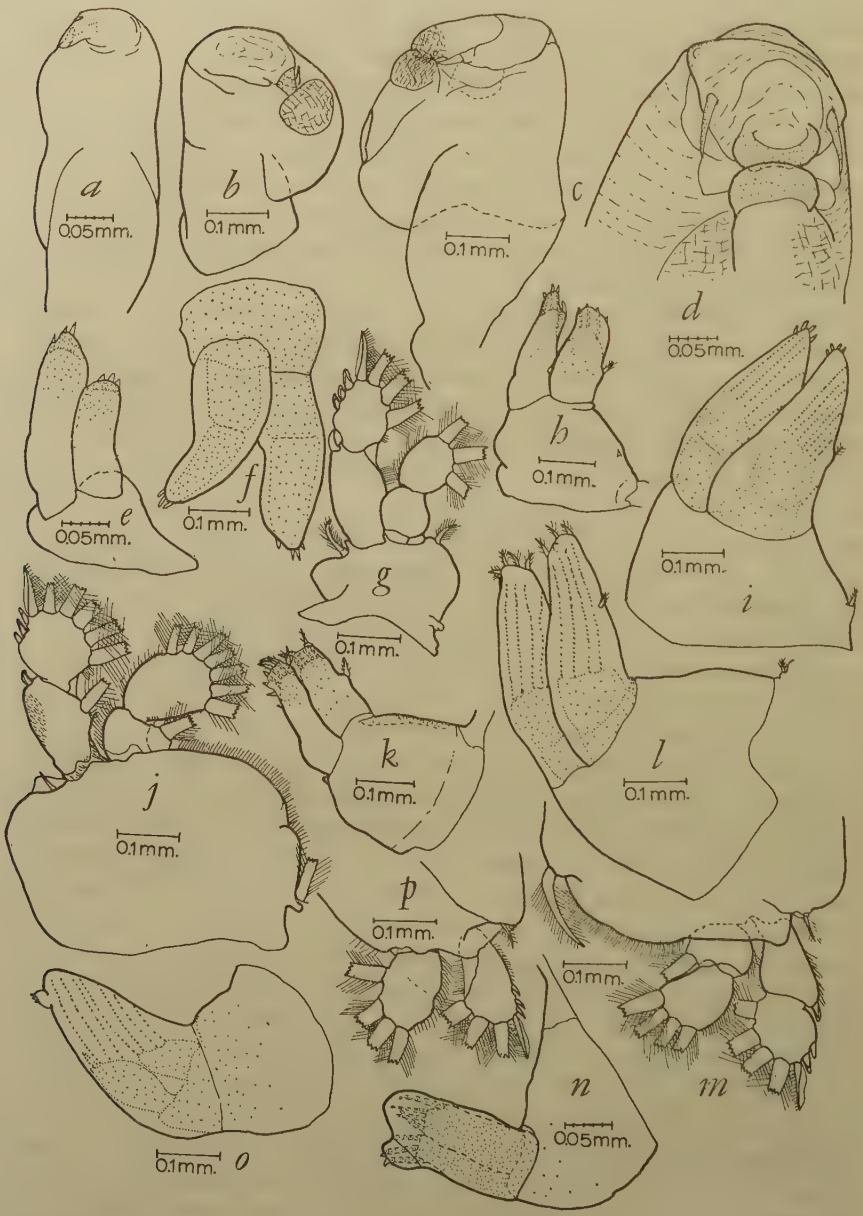

FIGURE 21.—*Nesippus costatus?* Wilson, 1924: *a*, maxilliped of younger early encysted specimen; *b*, maxilliped of older early encysted specimen; *c*, maxilliped of late encysted and recently excysted specimens; *d*, inner distal surface of *c*; *e*, first thoracic leg of younger early encysted specimen; *f*, first thoracic leg of older early encysted specimen; *g*, first thoracic leg of late encysted and recently excysted specimens; *h*, second thoracic leg of younger early encysted specimen; *i*, second thoracic leg of older early encysted specimen;

distal margin. Endopodite of both specimens with three plumose setules from distal margin, one plumose setule from middle of inner margin. Segments of both rami of late encysted forms visible inside rami of early encysted form (figs. 21*k*,*l*).

Third thoracic leg of late encysted and recently excysted specimens biramous. Protopodite broad, greatest length about three-fourths greatest width, with single plumose seta on inner proximal margin, single plumose setule just outside base of exopodite. Expodite two-segmented; first segment longer than second, narrower proximally than distally, with single spine from outer distal corner. Second segment of exopodite broadly rounded, almost orbicular, lateral and distal margins continuous; with two membrane-margined spines on outer margin. Endopodite two-segmented; first segment shorter than second, flared rapidly from narrow proximal to broad distal surface. Second segment narrower proximally than distally, lateral and distal margins distinct (fig. 21*m*).

Fourth thoracic leg of early encysted forms uniramous, two-segmented. Protopodite one-segmented, slightly wider than long; ramus and protopodite flaccid. Ramus with rounded protrusion from distal portion of outer surface, larger in younger than in older specimen; two minute, pointed projections present on protrusion in younger specimen, three in older. Both exopodite and endopodite of late-encysted specimens visible inside single ramus of early encysted specimens (figs. 21*n*,*o*).

Fourth thoracic leg of late encysted and recently excysted forms biramous, rami one-segmented. Protopodite longer than wide, outer surface with distinct groove giving bilobed appearance, with single plumose setule lateral to outer margin of exopodite. Exopodite narrower at proximal than at distal end, with three spines on distal portion of outer margin, each with light membranous margin. Endopodite oblong, with small but distinct indentation of inner margin, indistinct, discontinuous groove visible extending part way across segment from indentation (fig. 21*p*).

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j, second thoracic leg of late encysted and recently excysted specimens; *k*, third thoracic leg of younger early encysted specimen; *l*, third thoracic leg of older early encysted specimen; *m*, third thoracic leg of late encysted and recently excysted specimens; *n*, fourth thoracic leg of younger early encysted specimen; *o*, fourth thoracic leg of older early encysted specimen; *p*, fourth thoracic leg of late encysted and recently excysted specimens.

The character of the membranes, spines, and setae of the thoracic legs of the late encysted and recently excysted specimens is given below (for explanation of symbols, see figure 1):

Leg	Margin	Protopodite	Exopodite		Endopodite	
			1	2	1	2
I	outer	p	H	3H, Q		c
	inner	p	c	c, 3P		3P
II	outer	s	H	3H, Q	c	c, 3P
	inner	P, c	c, P	c, 5P	P	c, 4P
III	outer	p	c, H	2H, Q	c	c, 2P
	inner	P, c	c	4P	P	2P
IV	outer	p	c, 3H, Q		c	
	inner	P, c	c, 3P		4P	

The above table includes the armature of the thoracic legs of the late encysted and recently excysted forms only.

Caudal rami of early encysted forms long, conical, length about twice width; attached to posterior end of abdomen. Caudal rami tipped by four plumose setae. Anal region with two long, heavily chitinized, rodlike projections extending posteriorly from genital segment as far as caudal rami. These structures are incorporated into the abdomen of later encysted specimens and do not extend past the posterior end of the abdomen (figs. 20*a*,*b*).

Caudal rami of late encysted and recently excysted forms shorter than those of early encysted specimens, of laminate nature; attached to lateral surface of abdomen. Caudal rami with three long, plumose setae from distal and distal lateral surfaces, one from outer proximal region and one small, plumose seta from outer proximal region (not recorded by Wilson, 1924, for *N. costatus*). Inner margin of caudal rami setuliferous (fig. 20*c*).

Remarks.—The peculiar habit of encysting on the fins of teleost fishes exhibited by the male has not been reported previously in the literature for members of the family Pandaridae. The cyst appears to serve as a protective structure for the developing copepod and to replace the normal attachment cord or second antennal attachment of the chalimus stages of other copepods. The encystment of the copepod does not appear to harm the host to any extent and, when the male excysts, the cyst is absorbed by the host. Empty cysts in various stages of absorption were seen on the fins of teleost fishes, some being visible only as a slight irregularity.

The moult of the form described as the older early encystment stage was frequently found in empty cysts. One of the specimens included in the collection deposited in the U.S. National Museum was moulting when preserved. The moult of this specimen was that of the older early encystment stage, the specimen was in the late encystment stage; no additional moults were observed in the cyst. The moult suggests that at least two stages are passed within the cyst. Whether or not the copepod encysts more than once during its development has not been determined. A specimen in the late encystment stage was removed from its cyst and kept alive for seven days, during which time no change occurred in the animal.

Live copepods, when removed from their cysts, were extremely flexible. This condition is presumably useful during excystment, when the animal backs out of the opening at the end of the ovoid cyst. The opening was present in all of the cysts examined and the tips of the caudal rami of the copepod were observed protruding from the opening. Since copepods purportedly have anal respiration (Wilson, 1905), it appears that this opening serves for respiration and excretion.

All of the type specimens of *Nesippus costatus* Wilson, 1924, and the only specimens known for this copepod, have been lost. For this reason, definite identification of the copepod described here is impossible. The similarity of the late encysted and recently excysted forms to the description of the male of *N. costatus* given by Wilson (1924) indicates that the specimens described here are probably specimens of this species. The differences between the described specimens and the male of *N. costatus* are given in the preceding description.

Family Anthosomatidae

Genus *Norion* Nordmann, 1864

Diagnosis.—Body ovoid, strongly flattened dorsoventrally. Body, except cephalon, maxilliped-bearing segment, and first thoracic leg-bearing segment, covered with shield consisting of single dorsal plate over posterior surface, paired dorsal plates over anterior surface, and single pair of ventral plates, modified second thoracic legs, covering posterior ventral surface. Single posterior dorsal plate and ventral plate pair-forming brood pouch. Abdomen small, ovoid. Eggs in uniseriate strings curled inside brood pouch. Antennule seven-segmented; first pair of thoracic legs reduced, second pair forming ventral plates, third pair lamelliform, fourth pair dactyliform protopodite with rami reduced to minute lobes. Caudal rami obovate.

Remarks.—Nordmann erected this genus for the species *N. expansus* on the basis of a single specimen from the gills of an unknown fish captured in the Hawaiian Islands. The genus was placed by Nord-

mann in the family Chondracanthidae although Bassett-Smith (1899) and Wilson (1922, 1932), recognizing its affinities with members of the Caligoida, placed it in the family Dichelesthiidae. The overall appearance of the body and the specific appearance of the oral appendages and the cephalothorax indicate its relationship to species of *Anthosoma*, *Lernanthropus*, and *Sagum*. *Norion* differs from these genera by its extreme dorsoventrally flattened condition, the paired ventral plates that are neither bifid nor produced, and the reduced first thoracic legs. Because of the similarities of the four genera, *Norion* is placed in the family Anthosomatidae with these genera, the latter originally being a subfamily of the family Dichelesthiidae.

Norion expansus Nordmann

FIGURES 22*a–c*, 23*a–k*

N. expansus Nordmann, 1864, pp. 489–491, pl. 6.—Bassett-Smith, 1899, p.469.—Wilson, 1922a, pp. 26–27.

PRESENT HOSTS (original host unknown).—*Naso lituratus* (Bloch and Schneider), *Naso hexacanthus* (Bleeker).

DISTRIBUTION.—Hawaii.

MATERIAL.—Adult female collected by author from gill lamellae of specimen of *Naso lituratus* (Bloch and Schneider) speared by author off Lehua Rock, Niihau, Hawaii. Two adult females collected by author from gill lamellae of two specimens of *Naso hexacanthus* (Bleeker) taken in fish traps between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Two adult females collected by Dr. Hilda Ching from gill cavity of unknown species of *Naso* speared by Edgar Hookano off Kahuluu, Oahu, Hawaii. (USNM 105113–105116.)

MEASUREMENTS.—Average of greatest length 7.91 mm.; range 6.52–9.02 mm. Average length from anterior margin of head to posterior margin of body 6.72 mm.; range 5.70–7.91 mm. Average of greatest width 6.07 mm.; range 5.15–7.36 mm. Average length of fused cephalon, maxilliped-bearing segment, and first thoracic leg-bearing segment 1.29 mm.; range 1.10–1.56 mm. Average of greatest length from anterior end of second thoracic leg-bearing segment to posterior end of caudal rami 2.76 mm.; range 2.21–3.95 mm. Average of greatest length of single posterior dorsal plate 5.06 mm.; range 4.32–5.98 mm. Average of greatest length of paired dorsal plates 3.86 mm.; range 3.22–4.51 mm. Average of greatest length of paired ventral plates 5.43 mm.; range 4.51–6.90 mm.

DESCRIPTION.—Body yellowish brown in life, with fine, lighter colored vessels around margins of plates. Vessels filled with red fluid in living specimens that may form part of circulatory system; fluid flowing intermittently in response to movement of animal.

Body ovoid, anterior half, except cephalon, maxilliped-bearing segment, and first thoracic leg-bearing segment, covered dorsally by pair of plates projecting anteriorly on either side of head and forming U-shaped depression from apex of which uncovered cephalothoracic portion of body projects. Anterior margins of projecting plates broadly rounded, posterior medial margins irregularly convex; anterior dorsal plates attached to dorsal and lateral surfaces of second thoracic leg-bearing segment. Posterior dorsal portion of body covered by single, broad plate projecting posteriorly past caudal rami for distance equal to length of entire body, excluding plates. Lateral margins of single dorsal plate tapered to evenly rounded posterior end. Lateral margins broadly rounded anteriorly; anterior margins slightly concave, curving anteriorly to evenly rounded anterior median apex. Posterior lateral surfaces of paired dorsal plates overlapping anterior lateral surfaces of single plate. Single posterior dorsal plate attached along entire dorsal surface of third thoracic segment. Second thoracic legs greatly expanded, forming platelike structures covering entire ventral surface posterior to cephalothorax, extending posteriorly almost as far as posterior dorsal plate and anteriorly, along ventral surface of paired dorsal plates, to middle of cephalothorax. Second thoracic legs and posterior dorsal plate form brood pouch. Dorsal and ventral plates attached along adjacent margins by membranes. Surface of all plates covered with minute bumps (figs. 22*a–c*).

Cephalon, maxilliped- and first thoracic leg-bearing segments fused, forming cephalothorax, separated from rest of body by distinct groove though first thoracic leg-bearing segment overlapping second slightly on both dorsal and ventral surfaces (figs. 22*b*, 23*a*). Cephalothorax oblong, wider than long. Anterior and lateral margins of head irregular. Ventral surface of cephalon with padlike structures on lateral and anterior surfaces leaving central depression from which appendages and mouth cone arise (fig. 23*a*). First thoracic leg-bearing segment slender, anterior margin concave on ventral surface; first thoracic legs reduced, forming padlike structure, with concave depression on anterior surface to receive maxillipeds (fig. 23*a*). Second thoracic leg-bearing segment slender, much wider than long, distinct from first thoracic leg-bearing segment and third thoracic leg-bearing segment; anterior surface pocket-shaped for rotation of cephalothorax. Posterior ventral surface of second thoracic leg-bearing segment heavily chitinized in lateral regions, forming base for modified, platelike second thoracic legs attached to segment by narrow, pedunculate extension of proximal region of legs. Third thoracic leg-bearing segment large, expanded medially, larger than all other segments; lateral margins faint but distinct, tapered into single poste-

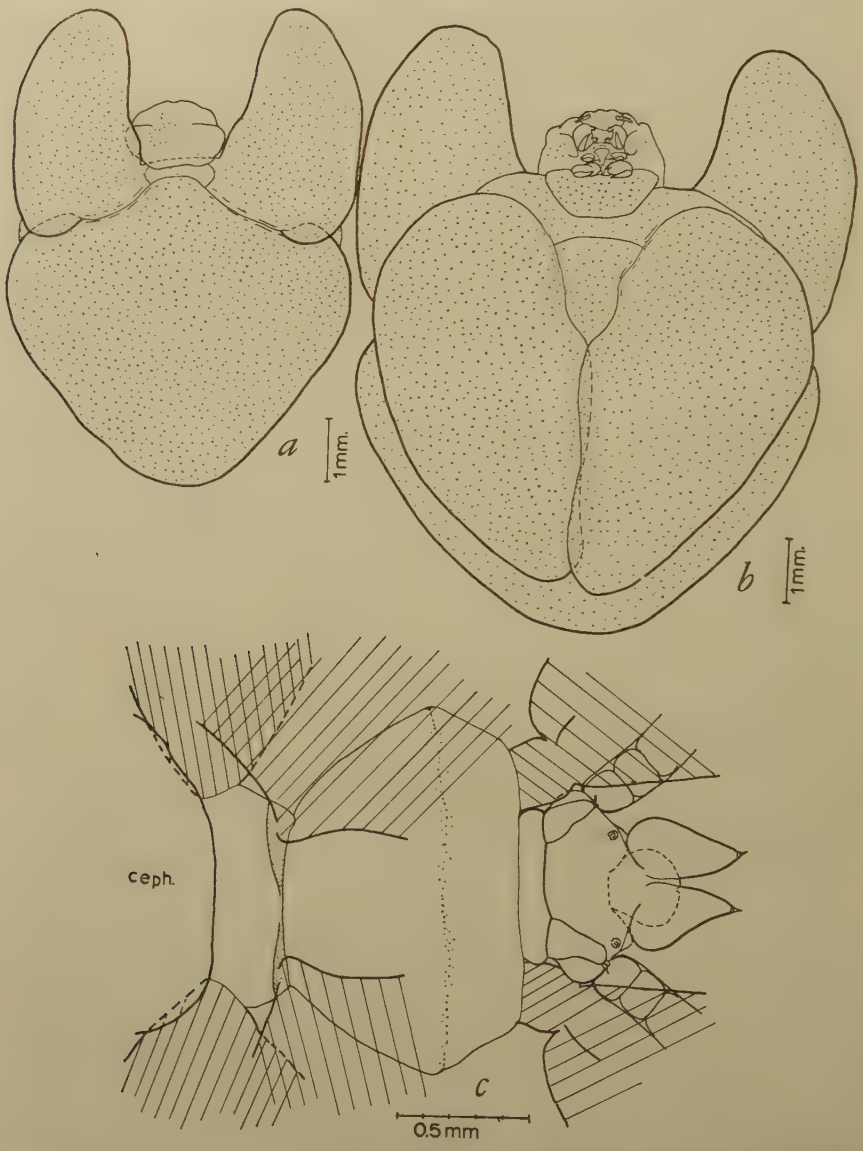

FIGURE 22.—*Norion expansus* Nordmann, 1864 (female): *a*, dorsal view; *b*, ventral view of second specimen; *c*, ventral view of posterior end of cephalothorax (ceph.), second, third, and fourth thoracic leg-bearing segments, genital segment, abdomen (dashed line), and caudal rami (parallel lines indicate position of plates and expanded third thoracic legs).

rior dorsal plate fused to dorsal surface of segment. Fourth thoracic leg-bearing segment slender, width greatly exceeding length, distinctly separated from third thoracic leg-bearing segment and genital seg-

ment. Genital segment expanded from anterior junction of fourth thoracic leg-bearing segment to widest point in anterior medial region of segment; lateral margins sharply curved, tapered posteriorly. Posterior and posterior lateral areas with double margin; posterior margin convex dorsally, abdomen joined to median portion; ventral margin tapered to region of fusion of genital segment, abdomen, and caudal rami. "Brown body" (Heider, 1879, for *Lernanthropus*) present at opening to spermatophore duct located on ventral posterior lateral surface of genital segment; circular, varying from brownish red to bright red in alcohol. Abdomen one-segmented, of a general ovoid shape; greatest length twice that of fourth thoracic leg-bearing segment, posterior end broadly rounded (fig. 22*c*).

Egg strings long, uniseriate, coiled inside brood pouch, each string consisting of more than 300 eggs. Eggs "fanned" by vertical movements of single posterior dorsal plate in living, ovigerous specimens (fig. 23*k*).

Antennule seven-segmented, attached to swelling on anterior ventral surface of cephalon. Segments of irregular shape and size, appendage tapered irregularly from large proximal to small distal regions. Second segment with three naked setae on anterior margin; third with one; fourth with minute naked seta on posterior margin; fifth segment with two naked setae on anterior distal margin and one on posterior margin; sixth segment with one long and one short naked seta on anterior distal margin; seventh segment with one long, three short naked setae from distal margin, two minute naked setae from posterior margin (fig. 23*b*).

Second antenna two-segmented, attached posterior to antennule-bearing swelling, on anterior ventral surface of head. First segment strongly developed, curving medially, distal end at right angle to proximal and directly over inner proximal corner. No distinct articular surfaces visible on proximal end of first segment, segment firmly attached to cephalon along entire proximal surface indicating little movement. Second segment short, with strongly developed terminal process. Terminal process of second segment curving strongly inwards, triangular in cross section, inner surface flat (fig. 23*c*).

Mandible appears four-parted. First part with broad proximal end, irregularly tapered to narrower junction of second part. Second part short, less than one-third length of first part, tapered evenly but abruptly to junction of third part, indicated by slight indentation on outer surface. Third part approximately twice length of second, slender, with little taper. Fourth part slightly longer than first, bent slightly but abruptly in proximal region, distal portion straight,

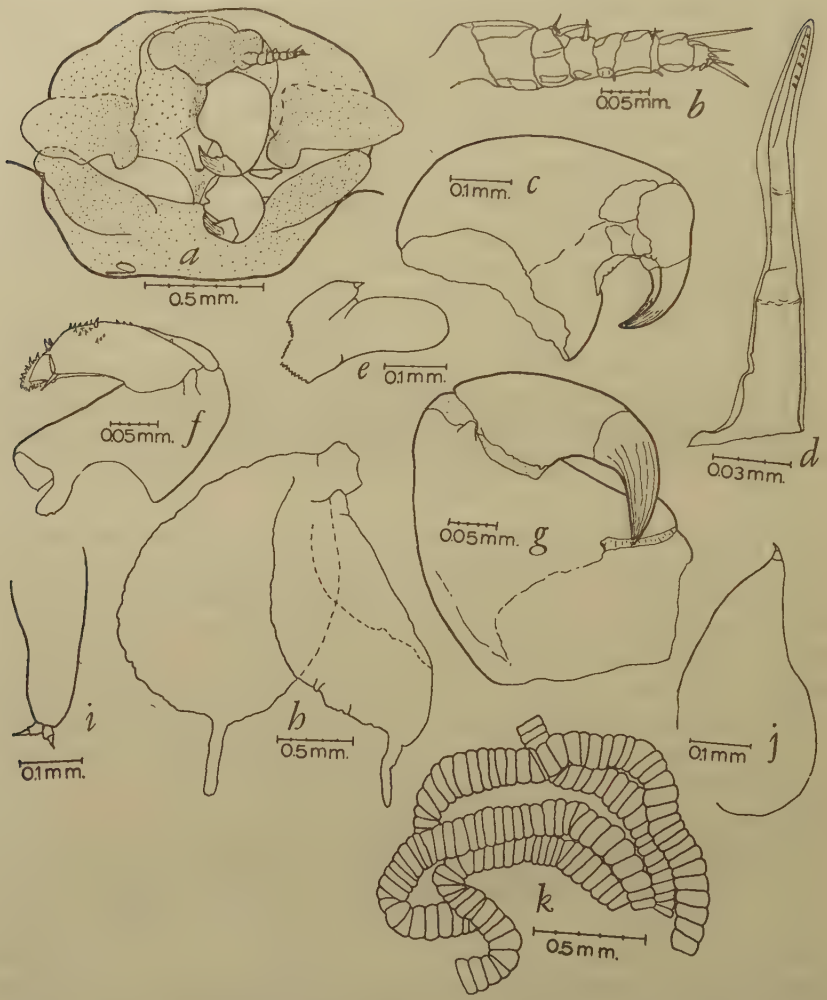

FIGURE 23.—*Norion expansus* Nordmann, 1864 (female): *a*, ventral view of cephalothorax; *b*, antennule; *c*, second antenna; *d*, mandible; *e*, postoral process; *f*, maxilla; *g*, maxilliped; *h*, third thoracic leg; *i*, fourth thoracic leg; *j*, caudal ramus; *k*, portion of egg string.

with six small, conical tubercles projecting from flat inner surface. Entire mandible surrounded by fine, membranous covering (fig. 23*d*).

Postoral process biramous, attached lateral to base of mouth cone, segmentation not visible. Outer ramus lamellate, inner dactyliform; inner ramus with short spine projecting from rounded distal end. Outer ramus about twice length of inner, without processes (fig. 23*e*).

Maxilla two-segmented, situated lateral and posterior to postoral process. First segment well developed, slightly longer than second, inner proximal surface projecting as well-developed, lobate, articular

surface. Proximal end of first segment irregular, outer lateral margin convex, inner straight; inner distal margin irregular, with slight articular surface protruding from segment, articulating with slight concave depression of second segment. Second segment curved inward, middle of outer surface with several small clusters of spinules, distal surface with several spinules and bearing terminal process denticulate along inner and outer margins (fig. 23*f*).

Maxilliped two-segmented, attached just posterior and medial to maxilla. First segment strongly developed, proximal end broad, distal narrow, taper primarily on inner surface, outer margin convex. Inner margin irregular, with shelflike formation at proximal end. Distal inner surface of first segment irregular, with two nodelike protrusions, one on posterior surface, second on anterior; protrusions projecting slightly above margin and forming articular surfaces for second segment. Second segment short, heavily chitinized, curved inward; terminal process well developed, spinelike, curved inward. Length of second segment and terminal process approximately two-thirds length of first segment, division between terminal process and segment distinct (fig. 23*g*).

The first and second thoracic legs have been described in the discussion of the body and will not be included in the following descriptions of the thoracic legs.

Third thoracic leg biramous, projecting from posterior lateral margin of third thoracic segment; lamellate, segmentation not visible. Endopodite slightly longer than exopodite, exopodite folded along midline, attached to endopodite along proximal margins. Both endopodite and exopodite with elongate, distally rounded extensions from rounded distal margin; length of extensions almost one-fourth length of appendage (fig. 23*h*).

Fourth thoracic leg biramous, attached to lateral posterior surface of fourth segment. Protopodite large, dactyliform, slightly wider at proximal than at rounded distal end. Exopodite and endopodite minute, one-segmented processes from distal end of protopodite, each tipped by small, spinelike process (fig. 23*i*).

Caudal rami obovate, laminate, greatest length slightly less than two times greatest width; proximal margin indistinct, rami fused to abdomen and posterior surface of genital segment. Outer margin with distinct bulge in proximal portion, pointed distal end tipped by minute, two-parted, spinelike process (fig. 23*j*).

Remarks.—The above description represents the first time this species has been described from specimens since Nordmann's original description (1864). Nordmann indicated that *N. expansus* was similar to members of the cyclopoid genus *Tucca* although both

Bassett-Smith (1899) and Wilson (1922), without seeing the holotype and only specimen, placed the genus *Norion* with the Caligoida.

Nordmann (1864) indicates that he found no evidence of body segmentation other than the presence of appendages in the cephalothorax. This was probably due to the covering of the posterior portion of the body by the single dorsal and paired ventral plates. With sufficient material at hand, this author has been able to examine members of the species in greater detail than did the original author.

The segmentation present in the specimens collected, the distinct segmentation of the antennule, the presence of four pairs of thoracic legs, and the presence of uniseriate egg strings indicate that this genus, represented solely by *N. expansus*, belongs in the Caligoida, not the Cyclopoida. The fusion of the first thoracic leg-bearing segment, the maxilliped-bearing segment, and the cephalon, in addition to the presence of dorsal plates, indicates that the species is a member of the family Anthosomatidae. The similarities of the single dorsal plate covering the posterior surface of the animal and the paired ventral plates found in *N. expansus* to those of some members of the genus *Sagum*, *S. angulatum* (Krøyer), and those of some members of the genus *Lernanthropus*, *L. pagelli* Krøyer and *L. chrysophrys* Shishido, indicate a distinct relationship between these genera. In addition, the maxilla of *N. expansus*, especially the distal end and terminal process of the second segment, is similar to that of members of the genus *Lernanthropus*, and the laminate third thoracic leg of *N. expansus* is similar to the fourth leg of species of the genus *Sagum*.

This parasite is comparatively rare in the Hawaiian Islands; the author collected three from 189 specimens of *Naso*, the only genus upon which the parasite was found. The additional two specimens were collected by Dr. Hilda Ching from a single, large specimen of an unknown species of *Naso*.

Family Lernaeoceridae

Genus *Peniculus* Nordmann, 1832

DIAGNOSIS.—Female: Body elongate; head without horns but lateral lobes may be present; separated from posterior body by neck consisting of thoracic leg-bearing segments 1–3 or segments 2 and 3, one being fused with cephalon in the latter. Fourth thoracic leg-bearing segment swollen, either separated from fused genital segment and abdomen by constriction or fused with these segments. Antennule reduced or absent; second antenna forming organ of attachment, terminal process clawlike, distinct in immature specimens, indistinct in mature. Mouth cone retractible; cephalic appendages consist of second antennae, mandibles, maxillae, and maxillipeds. Thoracic

legs platelike, composed solely of protopodite; fifth legs absent. Caudal rami armed with setae.

Remarks.—The diagnosis was taken from Olsson (1869) and Wilson (1932) although recent description of new species of this genus indicates the need for some revision. In addition to distinct morphological characteristics, the proportional relationships of the various body parts have been used as specific characteristics. The validity of this method, especially in a degenerated form such as that of the species in this genus, is dependent upon the degree of difference between the species and the number of specimens available; the amount of variation present, at least in the species described below, is sufficient to warrant careful consideration of the body parts being compared.

***Peniculus calamus?* Nordmann, 1864**

Figures 24*a–q*

P. calamus Nordmann, 1864, pp. 515–517, no figures.—Wilson, 1917, p. 45 [in key].—Shiino, 1956b, pp. 597, 599, 603.

Present hosts (original host unknown).—*Acanthurus dussumieri* Cuvier and Valenciennes, *Acanthurus mata* (Cuvier), *Acanthurus olivaceous* Bloch and Schneider, *Acanthurus triostegus sandvicensis* Streets, *Ctenochaetus strigosus* (Bennett), *Naso hexacanthus* (Bleeker), *Naso unicornis* (Forskål).

Type locality.—Hawaii.

Material.—Two mature females taken by author from caudal fin of specimen of *Acanthurus dussumieri* Cuvier and Valenciennes taken by poison off Waikiki, Oahu, Hawaii, by Dr. William Gosline and others. Four mature females taken by author from caudal fin of specimen of *A. dussumieri* captured in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. Six mature females taken by author from anal and pectoral fins of specimen of *Acanthurus mata* (Cuvier) captured in fish trap between Diamond Head and Koko Head, Oahu, Hawaii, by Samuel Kaolulo. (USNM 105110–105112.)

Measurements.—Average length from anterior end of head to posterior end of abdomen, excluding projecting second antennae and egg strings, 2.85 mm.; range 2.30–3.31 mm. Average of greatest length of head, excluding projecting second antennae, 0.32 mm.; range 0.29–0.36 mm.; average of greatest width 0.22 mm.; range 0.21–0.25 mm. Average of greatest length of neck (first, second, and third thoracic leg-bearing segments) 0.20 mm.; range 0.15–0.22 mm. Average of greatest length of combined fourth thoracic leg-bearing segment, genital segment, and abdomen 2.39 mm.; range 1.84–2.85 mm. Average length of egg strings (eight specimens) 2.94 mm.; range 2.12–3.86 mm.

679-677—64——7

DESCRIPTION.—Color of body brown in alcohol, egg strings yellow; body with dark brown splotches and dorsal black spot, the eye, on cephalon. The three pairs of spots on the underpart of the head as described by Nordmann (1864) were not found.

Cephalon ellipsoid dorsally, of general ellipsoid shape laterally, with ventral surface projecting in region of mouth cone. Dark eye spot present on dorsal surface, in middle of anterior portion of cephalon. Division between cephalon and first thoracic leg-bearing segment distinct, curving anteriorly on dorsal surface. First, second, and third thoracic leg-bearing segments forming neck. First thoracic leg-bearing segment short, tapered posteriorly, greatest width about twice greatest length. First segment overlapping second leg-bearing segment slightly, second segment slightly longer than first, tapered to junction of third thoracic leg-bearing segment. Third segment of varying length though generally equal to length of second leg-bearing segment. Posterior portion of third segment flared slightly at junction of fourth thoracic leg-bearing segment. Fourth leg-bearing segment expanded, fused to genital segment; fourth leg-bearing segment, genital segment, and abdomen forming elongate posterior portion of body. Indication of posterior end of fourth leg-bearing segment present as slight constriction in most specimens though absent in some. Anterior margins of fourth leg-bearing segment rounded, curved medially to junction of third segment (figs. 24*c*,*d*). Lateral margins of fused fourth thoracic leg-bearing segment, genital segment, and abdomen elongate, almost parallel; dorsal and ventral surface with several seta-like projections from epidermis but not projecting above cuticle in most specimens (fig. 24*d*). Abdomen small, projecting from posterior dorsal surface of genital segment; caudal projections overlapping caudal rami. The abdomen shows significant variation in the specimens examined; both long and short caudal projections were observed in the small series; bulbous and rounded terminations of the caudal projections were also seen (figs. 24*e*,*f*). Both of these variations were found in about equal proportions though the two do not appear to be related, forms with long abdomens being found with and without the bulbous terminations as also were forms with short abdomens (figs. 24*a*–*f*).

Egg strings long, with 36–42 eggs in each string. Distal end of string either rounded or projecting beyond last egg in string in tapered projection sharply rounded at tip (figs. 24*a*,*b*).

Antennule absent in all specimens.

Segmentation of second antenna indistinct, probably two-segmented. Appendage projecting anteriorly from anterior ventral surface of head, forming organ of attachment. Both second anten-

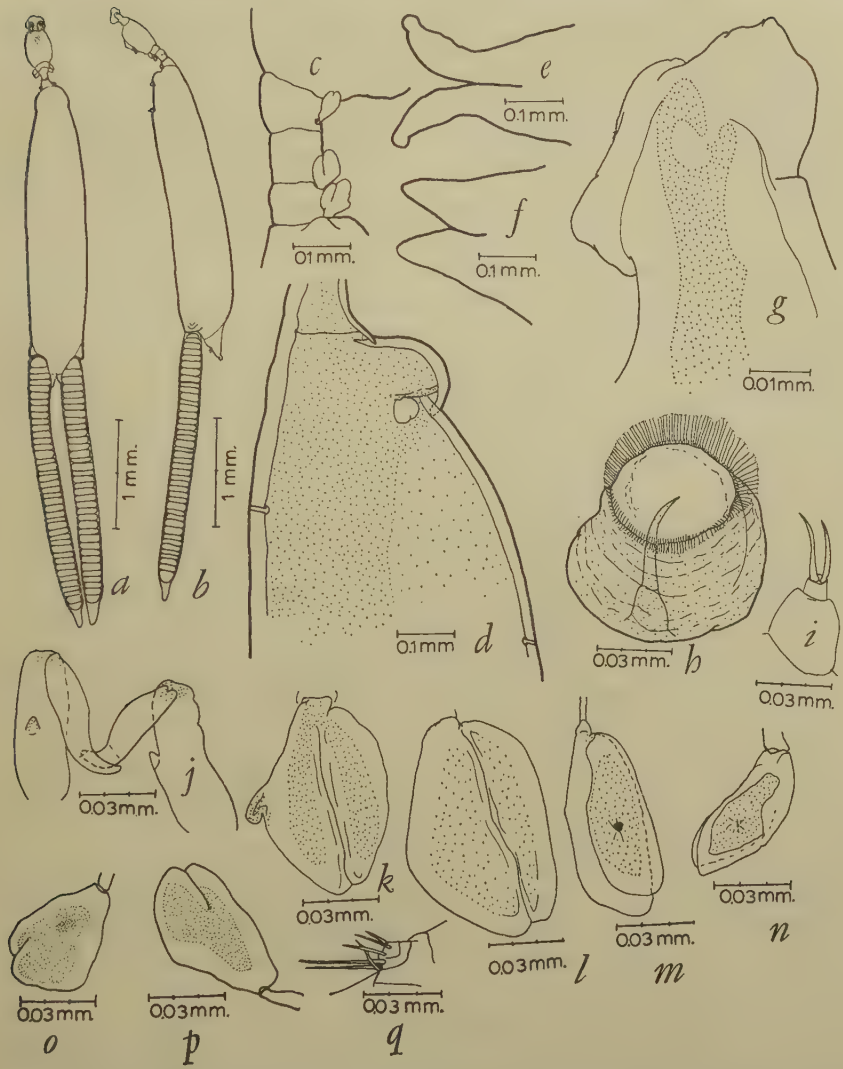

FIGURE 24.—*Peniculus calamus?* Nordmann, 1864 (female): *a*, dorsal view; *b*, lateral view; *c*, lateral view of neck; *d*, lateral view of swollen fourth thoracic leg-bearing segment and anterior part of trunk; *e*, dorsal view of abdomen; *f*, dorsal view of abdomen of second specimen; *g*, second antenna; *h*, mouth cone and mandible; *i*, maxilla; *j* maxilliped; *k*, first thoracic leg; *l*, second thoracic leg; *m*, third thoracic leg; *n*, fourth thoracic leg; *o*, *p*, fourth thoracic legs from different specimens; *q*, caudal ramus. (Stippling=red areas.)

nae buried in single, disc-shaped structure attached to fin rays of host. Disc-shaped structure formed from unknown material but presumably either from cement gland of copepod (frontal organ?) or outgrowth of fin rays of host though disc easily separable intact from

fin ray. Distal end of second antenna degenerate in adult, appearing to have been clawlike in younger stages (fig. 24*g*).

Mouth cone conical, protruding from median ventral surface of cephalon, distal surface slightly constricted, with membranous margin flaring outward from distal margin of cone (fig. 24*h*).

Mandible visible as elongate, acuminate process curving inward distally. Divisions not visible (fig. 24*h*).

Maxilla two-segmented, attached lateral to mouth cone. First segment slightly more than four times length of second, gibbous, with distal surface concave. Second segment truncate, with two seta-like projections from distal surface (fig. 24*i*).

The modification of this species is such that the naming of the oral appendages other than the mandibles is difficult. The above appendage is similar to the node on the anterior end of the postoral process in many caligids. Because of the lack of a complete developmental study and the lack of comparative studies with related groups, the appendage is termed a maxilla with reservation.

Maxilliped two-segmented, attached posterior to mouth cone. First segment approximately one and a half times length of second, greatest width slightly less than half greatest length; small protrusion on middle of inner surface. Second segment curving inward distally, terminating in blunt, rounded tip (fig. 24*j*).

In specimens preserved in alcohol, all of the thoracic legs possess a reddish area in the middle of the protopodite; this area is indicated on the figure of the appendage by stippling.

First thoracic leg ovoid, platelike, attached to anterior lateral surface of segment. Greatest width about two-thirds greatest length, distinct protrusion on middle of anterior margin and distinct groove extending from slight indentation on distal margin to proximal region of appendage (fig. 24*k*).

Second thoracic leg one-segmented, of general ovoid shape, attached to posterior lateral surface of segment; slightly larger than first thoracic leg. Median groove present as in first thoracic leg, extending from slight indentation on posterior distal margin proximally to proximal region of leg. Groove incompletely divides appendage into two unequal parts, anterior larger than posterior (fig. 24*l*).

Third thoracic leg ovoid, attached to posterior lateral surface of segment; without median groove but with indentation of distal surface. Third leg appears to consist of two lobate processes, smaller of two fused to lateral surface of larger. Proximal surface projecting slightly as tuberculate process, process attached to rod-shaped sternal plate (fig. 24*m*).

Fourth thoracic leg ovoid, much smaller than preceding thoracic legs. Shape of appendage variable (figs. 24*n–p*); median groove present, extending into leg about one-fourth greatest length of appendage.

Caudal rami minute, projecting slightly from ventral surface of caudal projections of abdomen. Separated from abdomen by incomplete groove; two additional, incomplete transverse grooves in distal half of appendage. Caudal rami with six naked setae, three from apex, three from posterior lateral margin (fig. 24*q*).

Remarks.—Nordmann's description of *P. calamus* (1864) was made from a series of specimens. Since the original description, specimens of this species, including the type specimens, have not been examined. Although the length of the presently described specimens is considerably less than the 5 mm. noted by Nordmann for the type specimens, the specimens are placed tentatively in the species because of the general characteristics that they possess in common with those originally described by Nordmann for *P. calamus*.

Specimens of *P. calamus?* collected by the author are similar to *P. minuticaudae* Shiino in the general shape of the body, the makeup of the thoracic leg-bearing segments, the cephalic appendages, and the thoracic legs. The author is indebted to Dr. S. M. Shiino for comparing specimens of the Hawaiian species with his specimens of *P. minuticaudae*. According to Shiino (in correspondence), the Hawaiian specimens possess "a longer abdominal process which extends straight backward and is more deeply and more distinctly bilobed forming somewhat divergent lobes." In *P. minuticaudae* "the process is shorter, more shallowly bilobed and never extends straight backward, but remains to form a mere triangular stump in lateral view." These characteristics, in addition to others indicated by Shiino (in correspondence), suggest that, although the two species possess similar morphological characteristics, they are distinct.

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